RELATIONSHIPS BETWEEN LAND USE AND WATER QUALITY IN SOUTHWESERN ONTARIO

BY Gartner Lee Associates Limited

1986

Ministry
of the
Environment

D.A. McTavish
Director
Southwestern Region

RELATIONSHIPS BETWEEN LAND USE AND WATER QUALITY IN SOUTHWESTERN ONTARIO

FOR

MINISTRY OF THE ENVIRONMENT
SOUTHWESTERN REGION

BY

GARTNER LEE ASSOCIATES LIMITED

85-01-CA-68

MARCH 31, 1986

MOE
REL
ARJC

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March 31, 1986.

Ministry of the Environment,
Southwestern Region,
985 Adelaide Street S.,
London, Ontario.

Attention: Mr. Denis Veal

Dear Denis:

Re: Relationships Between Land Use and
Water Quality in Southwestern Ontario
GLAL 85-01-CA-68

We are pleased to submit our final report on land use and water quality relationships in Southwestern Region. The report presents an overview of the nature and extent of water quality impairment in the region resulting from land use activities, primarily agriculture.

Large water quality and land use data bases were analyzed for spatial and temporal relationships. Only the most significant findings are contained in this report. Supporting data are contained in a separate technical appendix to this report.

Thank you for the opportunity to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

D.S. Osmond

D.S. Osmond, B.Sc.Agr.
Associate

DSO:jw

ACKNOWLEDGEMENTS

This project was undertaken by Gartner Lee Associates Limited (GLAL) for the Ministry of the Environment (MOE), Southwestern Region. Technical guidance and review were provided by a Technical Steering Committee established by the Ministry. The committee consisted of the following people:

Mr. Denis Veal (Contract Liaison Officer)
Mr. Doug Huber
Mr. John Bray
Dr. Lloyd Logan

The contributions of the members of the Technical Steering Committee, staff of the Ministry of the Environment (water quality data), staff of the Ministry of Agriculture and Food (land use data) and respondents to the questionnaire are gratefully acknowledged.

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1.0 INTRODUCTION

1.1 BACKGROUND

As part of its mandate to oversee and manage the quality of provincial surface waters, the Ministry of the Environment (MOE) supervises an extensive water quality monitoring network across the province. Output from this network provides a picture of how water quality differs among the various administrative regions, how it has changed with time and how it relates to provincial water quality objectives.

Results of the monitoring program in southwestern Ontario indicate that treated wastewater sources from municipalities and industries as well as nonpoint sources from agricultural land are the major influences on water quality. While populations have expanded with time, so has wastewater treatment technology; hence, the influence of point sources has largely been stabilized. On the other hand, trends in agriculture over recent decades towards intensive drainage and row cropping, increased fertilizer and farm chemical use, larger farm units and larger livestock operations have resulted in a greater influence on water quality by agricultural land use. Streams have become enriched through runoff of fertilizers and erosion of soils resulting in heavy growth of aquatic plants and algae and wide diurnal variations in dissolved oxygen in stream waters. Runoff from poorly managed and designed feedlots has created bacteriological problems and fish kills have arisen from poor silage, fertilizer, manure or pesticide management practices.

Documentation of the influence of agricultural land use on water quality is available in several reports and in the water

quality monitoring results. Previously this information has not been drawn together, digested and presented in a manner that clearly highlights issues for the public and water resource managers alike.

1.2 PREVIOUS STUDIES

Between 1972 and 1978 landmark studies of nonpoint source pollution in the Great Lakes Basin were undertaken as part of the Pollution from Land Use Activities Reference Group (PLUARG) under the auspicies of the International Joint Commission (IJC). PLUARG was a major international cooperative effort between the United States and Canada to investigate pollution of the Great Lakes system from land use activities. The numerous studies undertaken provided the most exhaustive review of nonpoint source pollution conducted in the Great Lakes basin at the time and continue to provide a valuable data base and reference source.

PLUARG (1) found that the Great Lakes were being polluted from land drainage sources by phosphorus, sediments, some industrial compounds, some previously used pesticides and potentially some heavy metals. Intensive agricultural operations were identified as the major diffuse source contributor of phosphorus. Erosion from crop production on fine textured soils and from urbanizing areas were identified as the primary sources of sediment. Urban runoff and atmospheric deposition were found to be the main sources of toxic substances.

The most important land related factors affecting the magnitude of loads from nonpoint sources were soil type, land use intensity and materials usage. For example, intensive row

cropping (corn, soyabeans) on fine textured soils (i.e. high clay content) contributed the highest amounts of phosphorus.

PLUARG submitted its final report to the International Joint Commission in 1978. Among PLUARG's numerous recommendations was the development of management plans stressing site specific approaches to reduce pollutant loadings.

Numerous reports and papers have been published documenting the PLUARG findings. In addition, several studies have been undertaken in the Southwestern Region since PLUARG to address specific water quality problems. A few of the more important studies are listed below:

- Stratford-Avon River Environmental Management Project (2)
- Water Quality studies of Rondeau Bay and Watershed Kent County (1982) (3)
- Lake Huron Beaches Factors Affecting Microbiological Water Quality in 1984 (4)

In 1978, the United States and Canada signed a Great Lakes Water Quality Agreement that established phosphorus reduction targets for the lower Great Lakes. By this time it was becoming clear that further reduction in phosphorus loadings were feasible only through significant reductions in nonpoint source phosphorus.

In 1981, the Water Quality Board of the IJC established a Nonpoint Source Control Task Force to review and evaluate the effectiveness of remedial practices and programs that have been initiated in the Great Lakes Basin to control nonpoint source pollution.

The Task Force submitted its final report to the Water Quality Board in 1983 (5). The Task Force found that the need for nonpoint source control programs had increased since 1978 due to intensifying use of farm land which has resulted in increased soil erosion. A review of Canadian programs determined that no action had been taken to develop a comprehensive program to address nonpoint source pollution in the Great Lakes basin. A number of programs were identified, however, which addressed specific components of the concerns raised by PLUARG. These programs included:

- short term watershed management studies
- demonstration programs
- ongoing field services
- special interest group activities
- policies, legislation and guidelines.

The Task Force report contains an overview of the various Canadian programs and an evaluation of the effectiveness of these programs. The report also discusses and evaluates a wide range of practices which are available for remedial action.

Since the Task Force submitted its report in 1983 the Governments of Canada, the United States, Ontario and the various U.S. states have been formulating comprehensive programs to deal with nonpoint source pollution.

Since 1964 the Ontario Water Resources Commission and later the Ministry of the Environment have operated the Provincial Water Quality Monitoring Network (PWQMN). This network was established to provide information on the water quality of Ontario's lakes and streams. Sampling stations in the PWQMN

have been selected to measure water quality at strategic geographic locations and to monitor the effects of point source waste water discharges and the effects of nonpoint source land uses. In the Southwestern Region most stations are situated on larger streams and therefore measure the combined effects of point sources and nonpoint sources.

An extensive water quality data base in the Southwestern Region has been assembled through the PWQMN. Previously there has been no attempt to analyse this information at a general level to investigate relationships between land use and water quality.

As is evident from this brief review of previous studies, a great deal of attention has recently been focused on the problem of nonpoint source pollution. Many of the studies have been of a very specific nature and limited to relatively small geographic areas. This study is the first attempt to provide an overview of general water quality at a regional scale and to link together previous studies and the extensive PWQMN data base.

1.3 STUDY OBJECTIVES

The general objective of this study is to prepare a report which defines clearly and simply the general nature and extent of water quality impairment resulting from agricultural land use throughout the MOE Southwestern Region.

To accomplish this general objective and to provide a focus for the work, a number of specific objectives were identified as follows:

- to illustrate the degree of water quality impairment, via violations of Provincial Water Quality Objectives;
- to determine differences in water quality throughout the Region, and reasons for these differences;
- to identify the land use activities that relate most closely to water quality;
- to show water quality trends over time, and reasons for these trends;
- to identify which water quality parameters are of greatest concern, and which ones require greater future attention;
- to present management suggestions arising from the analysis of water quality as related to land use; and
- to evaluate the results of this project in light of previous studies.

1.4 SCOPE

From the list of specific objectives, it is obvious that the project is very broad. The water quality and land use data bases available for input to the study are truly enormous. Furthermore, there are many specific studies which have supplementary data that are available for analysis.

At the outset of the study it was recognized that the challenge would be to simplify the existing data to its most meaningful base and to illustrate clearly the most obvious conclusions with regard to water quality and agricultural land use. To achieve the general objective of a clear and simple (to understand) report the study was restricted to a manageable number of water quality and land use parameters. The water quality and land use parameters considered are listed in Table 1.

TABLE 1: WATER QUALITY AND LAND USE PARAMETERS CONSIDERED

A. WATER QUALITY

Total Phosphorus
Total Nitrogen
Suspended Solids
Fecal Coliforms
Copper*

B. LAND USE

Beans
Corn
Pasture
Woods
Soil (silt and clay)
Number of farms
Number of sewage treatment plants
Hydraulic loading of sewage treatment plants
Tile Drainage
Livestock Intensity

* Subsequently dropped from analysis due to lack of data.

This report presents the most significant findings. For readers wanting more detailed information, the complete results of the analysis are available in an unpublished technical appendix to this report. Access to the technical appendix may be obtained by contacting Region staff.

1.5 APPROACH

The general study approach used to complete this project consisted of three steps. Further details on the methods used are contained in Chapter 2.

The first step of the study was to obtain all available water quality data, land use data and reports relevant to the study. This information was then compiled, reviewed and summarized. Next a meeting was held with the Technical Steering Committee (which oversees this project) to assess preliminary results and to fine tune the study scope and work plan.

The second step of the study was data analysis. The spatial analysis component was undertaken first. Then an analysis was undertaken to identify spatial correlations (between water quality and land use). Finally the trend analysis was undertaken on significant parameters identified in the spatial analysis. Results from other studies were incorporated into the analysis to assist in the interpretation of results. Included in this step was a review of study findings by and input from the Technical Steering Committee.

The final step was the preparation of the report. Since it was not possible to analyze a wide range of water quality and land use parameters a section on "other considerations" was included. Information contained in this section was drawn from other studies.

2.0 METHODS

2.1 DATA COLLECTION AND LITERATURE REVIEW

Water quality data used in this study were collected by the Ministry of the Environment under the Provincial Water Quality Monitoring Network (PWQMN). Information on the acreages of various agricultural land uses was available from the Ontario Ministry of Agriculture and Food (OMAF)(6, 7). Information on tile drainage was provided by OMAF.

Information on recent studies was obtained by contacting numerous researchers and local government officials (e.g. County Agricultural Representatives) by letter and phone.

Tile drainage information was available on approximately 120 Township maps. An approximation of the percentage of county area tile drained was determined in the following manner.

1. For each Township map four representative sub-areas were selected and the percentage tiled estimated. The average of the four sub-areas was calculated and recorded as the percentage of the Township tile drained.

2. Large townships consisted of two maps. In such cases four sub-areas were selected on each map. The Township value was derived by calculating the average for all eight sub-areas from the two maps.

3. Finally the "percentage tiled" figures were converted to absolute acreages and summed for each township. The total area tiled per county was then converted to a percentage of total county area.

Soil information was compiled from the map "Soil Association of Southern Ontario" (8). A "sensitive soil" parameter was derived which consisted of primarily clay and silt soil types.

2.2 ANALYSIS METHODS

2.2.1 SPATIAL

The first component of the data analysis step was the mapping of existing land use and water quality conditions for the most recent time period possible. The period 1980 to 1982 was selected as the time frame for the water quality spatial analysis. Since most stations in the PWQMN are sampled approximately monthly, it was decided that at least a three year period would be necessary to provide sufficient data for analysis. Since complete land use information was generally only available for census years it was decided to choose the most recent census year, i.e. 1981. The water quality data base was centred on this year.

The second component of the spatial analysis was to examine the land use and water quality data to identify correlations. The first level of analysis was simply a subjective evaluation of the spatial maps to highlight apparent relationships. The second level of analysis involved linear regression to establish relationships.

2.2.2 TRENDS

Water quality trends were determined by plotting the mean annual concentration of each water quality variable for each county from 1970 to 1982. An "ideal trend line" was then fitted by means of linear regression analysis. The slope of the trend line was then tested (Student's t test) to see if it was significantly different from zero. Tests were carried out at the 90% and 95% confidence levels.

Land use trends were established by plotting the available land use percentages versus time. Accurate measurements of land use were only available for census years. For row crops, estimates were available for non census years. Land use trends are based on a subjective evaluation of the plots and not on a statistical test.

2.3 REPORTING

In the interests of the preparation of a clear and understandable product, only significant findings are documented in this report.

The complete results of the data analysis undertaken during this study are contained in the Technical Appendix to this report.

Following is a list of some of the material included in the Technical Appendix:

1. analysis of copper data (there was insufficient data available for complete analysis therefore this parameter was dropped on the recommendation of the Technical Steering Committee.);

2. spatial maps showing the distribution of the complete range of land use and water quality parameters analysed;

3. trend plots for the complete range of water quality data analysed;

4. supporting data and printouts of the correlation and trend analysis;

5. data compilation sheets for tile drainage information, and

6. printouts of data bases compiled for this study.

In addition to the above-mentioned information raw water quality data and land use data bases are available on computer diskettes.

2.4 DATA LIMITATIONS

There are data limitations and qualifications concerning the analysis methods used that the reader should bear in mind when considering the results documented in this report. These limitations and qualifications are outlined below.

1. The four water quality variables selected for study in this report (i.e., total phosphorus, total nitrogen, suspended solids and fecal coliforms) are considered to be representative of general water quality conditions in the region. These variables were selected (in consultation with the Technical Steering Committee) because they were considered to be most pertinent to agricultural land use and because there were sufficient data available for analysis.

2. Stations in the PWQMN represent water quality conditions downstream of a variety of land uses and point sources. Specific effects of agriculture on water quality are difficult to ascertain.

3. The station locations and sample frequencies used in the PWQMN were not designed to address questions of land use and water quality relationships. As such, these data bases are not particularly well suited for regression analysis.

4. Land use information was available on a jurisdictional basis (i.e. county) rather than a watershed basis. To combine the data bases for input to regression analysis water quality data were compiled on a county basis (i.e. mean of all stations in a county). This compilation does not reflect natural variables such as drainage basin, physical setting, etc.

5. Many other land use factors and hydrologic factors undoubtedly influence water quality conditions in the region. This analysis investigates only a few of the factors thought to be most significant in Southwestern Region.

3.0 SPATIAL CHARACTERISTICS AND RELATIONSHIPS

3.1 INTRODUCTION

Many of the studies undertaken in the Southwestern Region have found that observed water quality problems in the region are related to land use characteristics and changes in land use patterns. For example, phosphorus and sediment problems have been linked to intensive row cropping practices, primarily bean and corn production, on clay textured soils (1). Nutrient enrichment and bacteriological contamination of streams and reservoirs have been attributed to livestock operations (9). Tile drainage has also been identified as an important factor in providing a rapid pathway from agricultural pollutant sources to streams (9, 10).

This chapter presents the spatial characteristics of selected land use activities and water quality variables for the period

1980-1982. It also attempts to identify correlations between land use activities and water quality.

3.2 LAND USE CHARACTERISTICS

3.2.1 INTRODUCTION

The distribution of selected agricultural land use parameters thought most likely to affect water quality is shown in Figures 1 to 5 for the ten counties in southwestern Ontario. The agricultural statistics have been grouped into three or four class intervals to represent relative levels of occurrence. In addition, the actual county ranking is plotted on a linear scale to enable comparisons among the counties. Land uses are reported as a percentage of total county area.

The spatial analysis was carried out for a total of 15 parameters; however, only those parameters for which significant correlations (i.e., >0.7) were identified are presented here (see Section 3.4). Figures and data for the complete range of parameters analysed are on file with the Ministry of the Environment, Southwestern Region.

3.2.2 TOTAL BEANS

The spatial distribution of beans in 1981 is shown in Figure 1. The information plotted represents the percentage of the total county area for which beans were grown. The statistics are for total bean production i.e. soya beans plus dry white beans. For this figure four class intervals were used to display relative differences of bean production. The classes were: high, medium, low and none.

Figure 1 clearly shows that the greatest bean production occurs in the extreme southwest, particularly in Essex, Kent

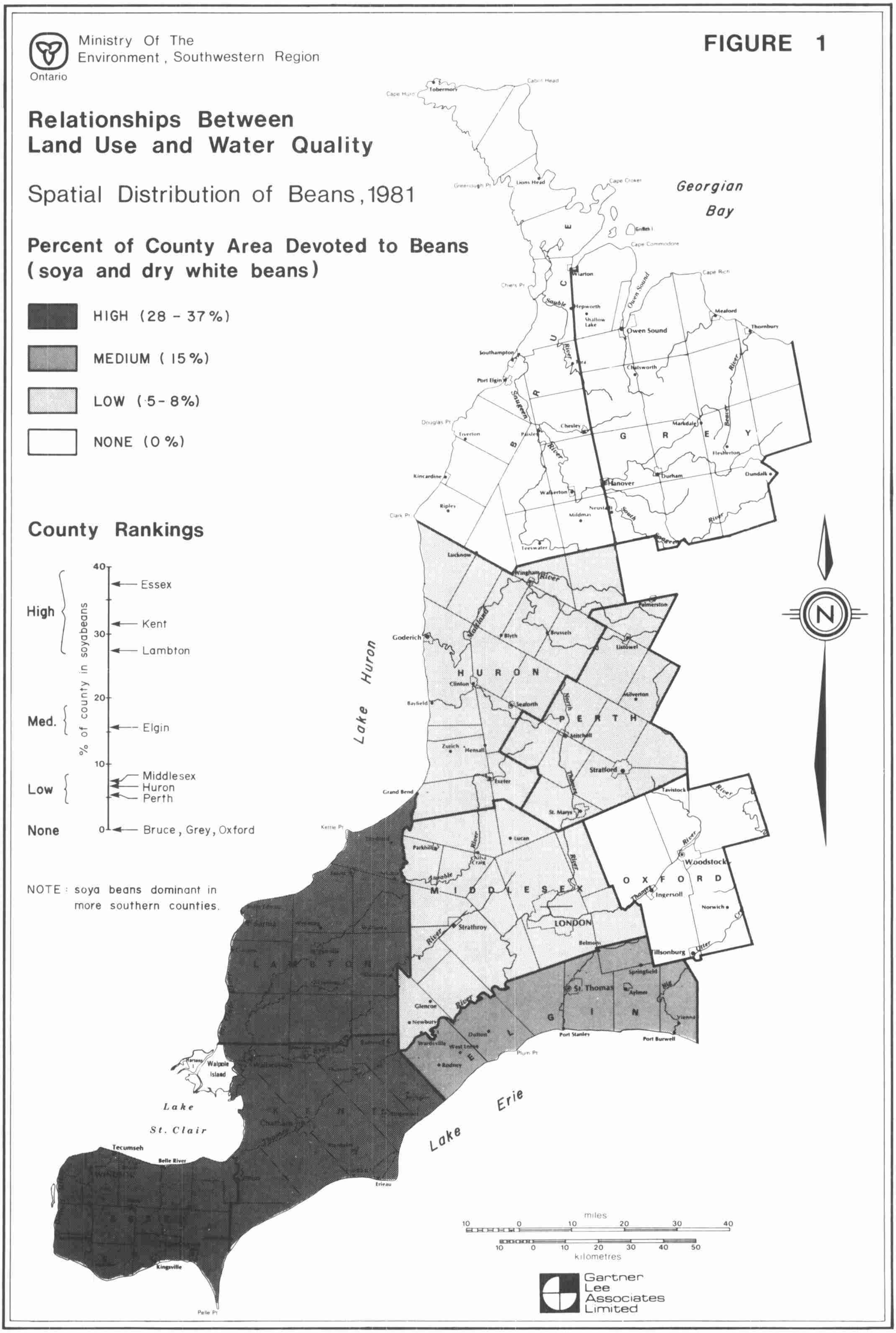
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FIGURE 1
Relationships Between
Land Use and Water Quality
Spatial Distribution of Beans, 1981
Percent of County Area Devoted to Beans
(soya and dry white beans)
HIGH (28 - 37%)
MEDIUM (15%)
LOW (5-8%)
NONE (0%)
County Rankings
% of county in soyabeans
High
Med.
Low
None
Essex
Kent
Lambton
Elgin
Middlesex
Huron
Perth
Bruce, Grey, Oxford
NOTE: soya beans dominant in more southern counties.
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
HURON
PERTH
MIDDLESEX
OXFORD
ELGIN
GREY
BRUCE
LONDON
Owen Sound
Goderich
Stratford
Woodstock
St. Thomas
miles
kilometres
Gartner Lee Associates Limited

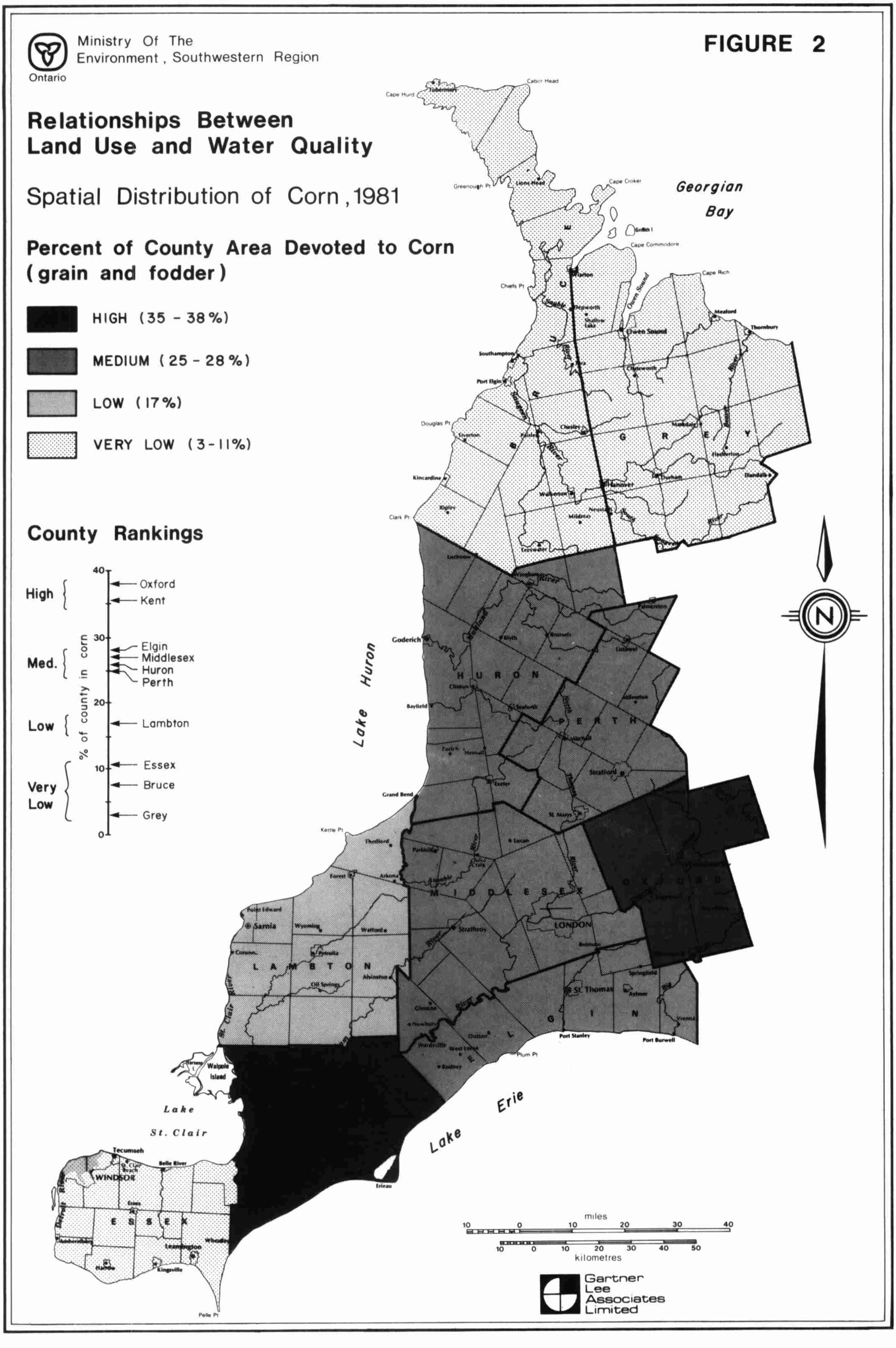
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FIGURE 2
Relationships Between
Land Use and Water Quality
Spatial Distribution of Corn, 1981
Percent of County Area Devoted to Corn
(grain and fodder)
HIGH (35 - 38%)
MEDIUM (25 - 28%)
LOW (17%)
VERY LOW (3-11%)
County Rankings
High
Med.
Low
Very Low
% of county in corn
40
30
20
10
0
Oxford
Kent
Elgin
Middlesex
Huron
Perth
Lambton
Essex
Bruce
Grey
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
G R E Y
H U R O N
P E R T H
M I D D L E S E X
L A M B T O N
E S S E X
E L G I N
Goderich
Sarnia
LONDON
Stratford
St. Thomas
WINDSOR
Owen Sound
miles
10 0 10 20 30 40
10 0 10 20 30 40 50
kilometres
Gartner Lee Associates Limited

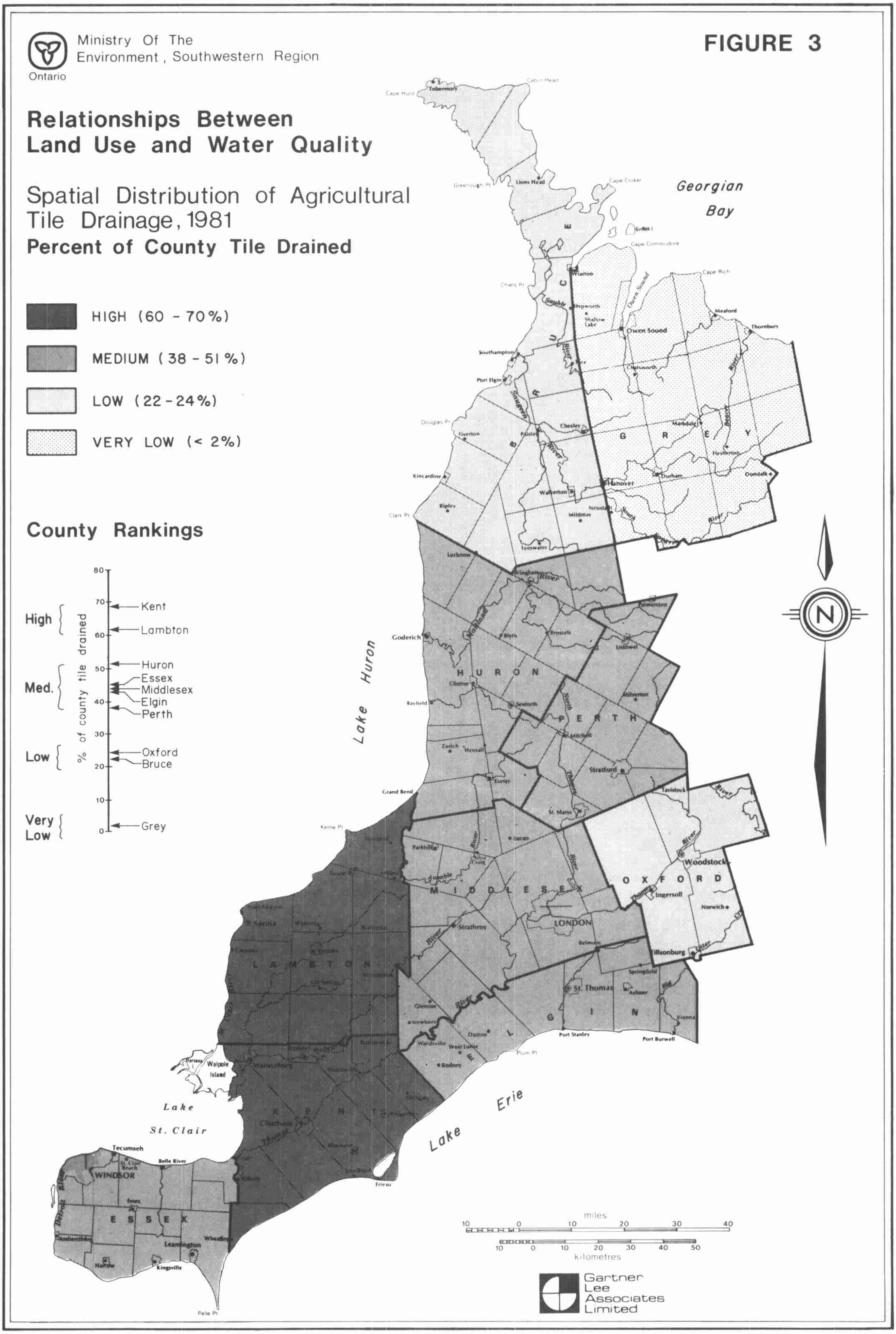
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FIGURE 3
Relationships Between Land Use and Water Quality
Spatial Distribution of Agricultural Tile Drainage, 1981
Percent of County Tile Drained
HIGH (60 - 70%)
MEDIUM (38 - 51%)
LOW (22-24%)
VERY LOW (< 2%)
County Rankings
High
Med.
Low
Very Low
% of county tile drained
80
70
60
50
40
30
20
10
0
Kent
Lambton
Huron
Essex
Middlesex
Elgin
Perth
Oxford
Bruce
Grey
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
B R U C E
G R E Y
H U R O N
P E R T H
O X F O R D
M I D D L E S E X
L A M B T O N
K E N T
E L G I N
E S S E X
Owen Sound
Goderich
Stratford
Woodstock
Ingersoll
LONDON
St. Thomas
Sarnia
Chatham
WINDSOR
Leamington
Kingsville
Harrow
Tecumseh
Walpole Island
miles
kilometres
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FIGURE 4

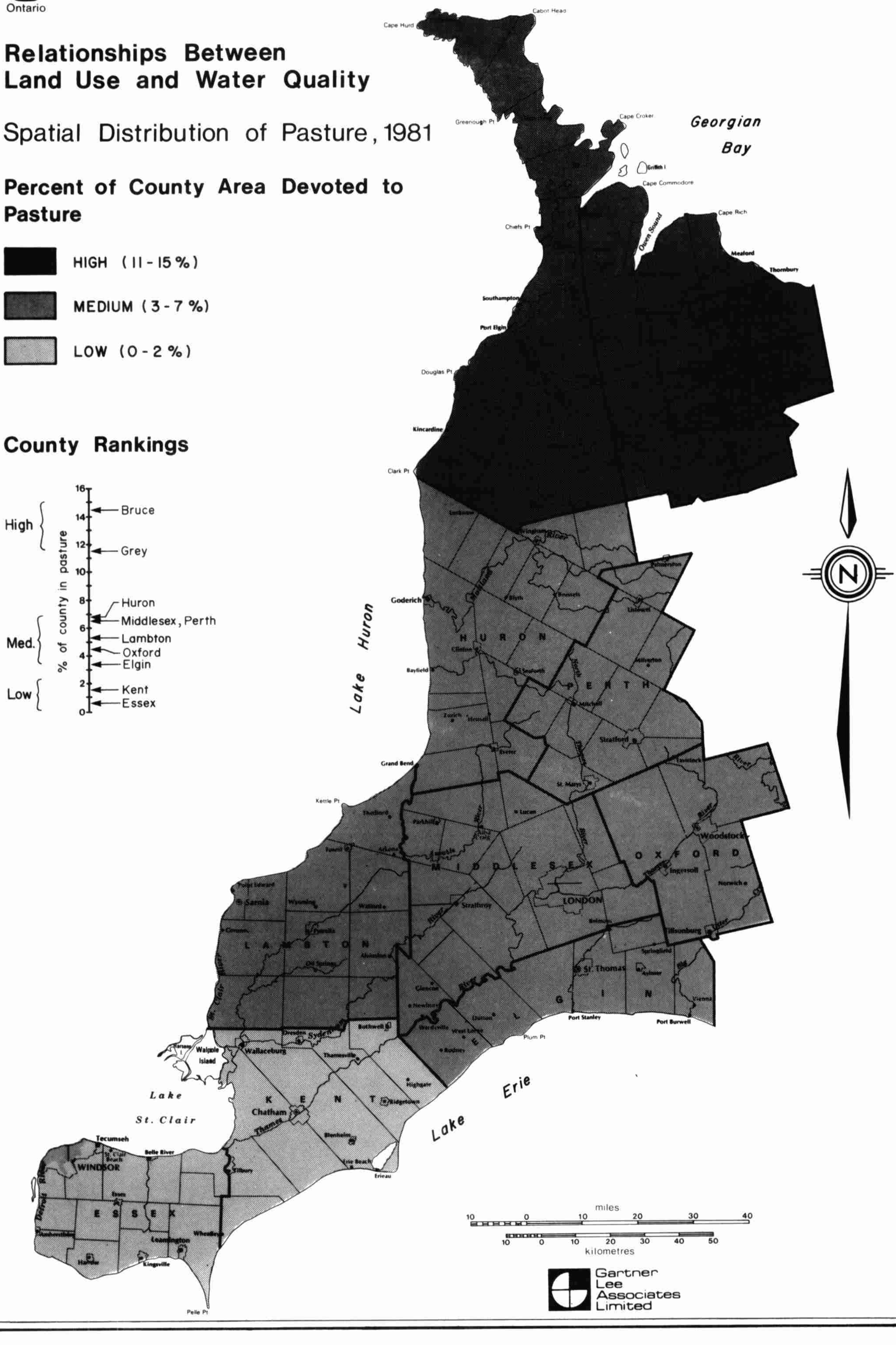
Relationships Between Land Use and Water Quality

Spatial Distribution of Pasture, 1981

Percent of County Area Devoted to Pasture

- HIGH (11 - 15 %)
- MEDIUM (3 - 7 %)
- LOW (0 - 2 %)

County Rankings



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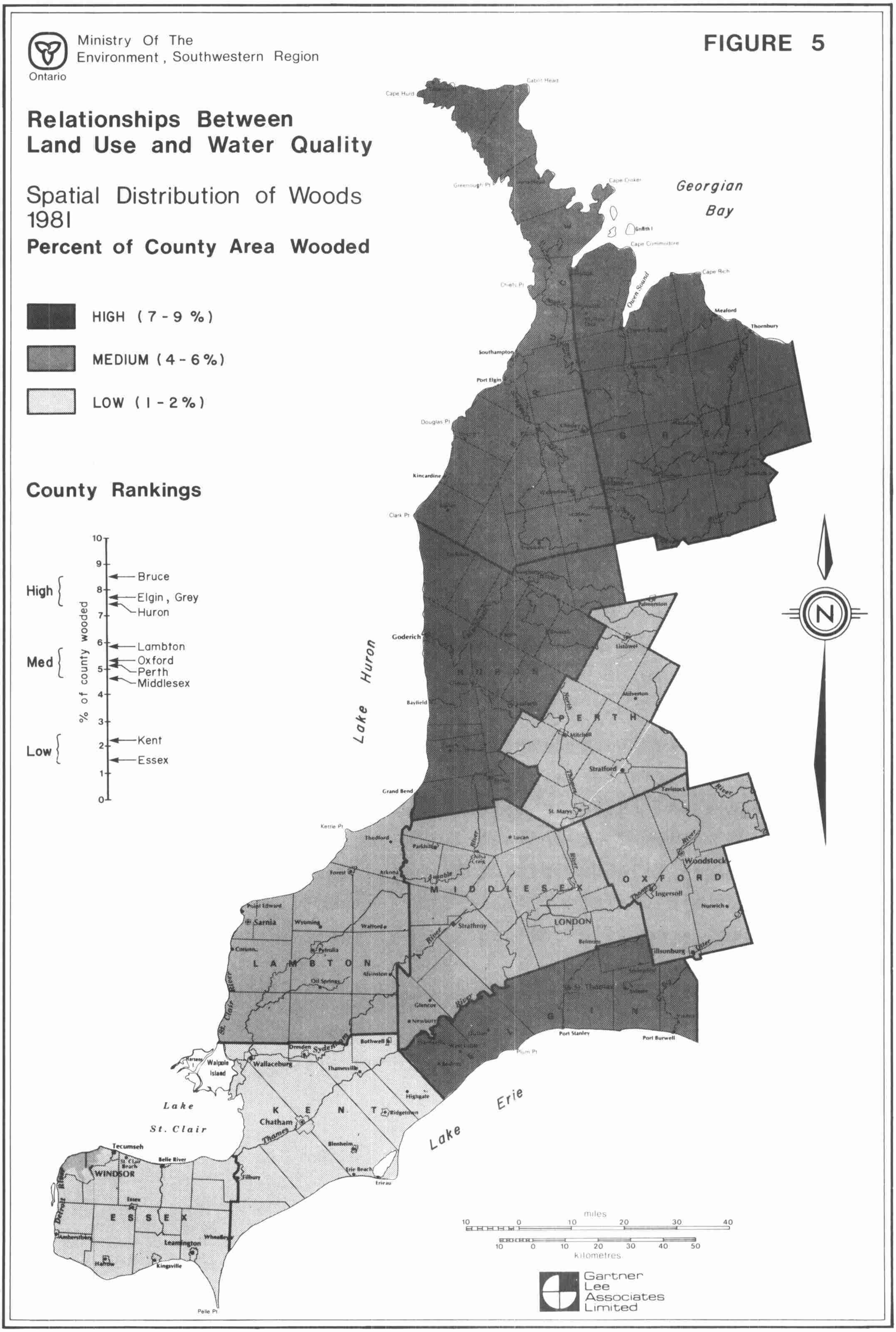
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FIGURE 5
Relationships Between Land Use and Water Quality
Spatial Distribution of Woods 1981
Percent of County Area Wooded
HIGH (7 - 9 %)
MEDIUM (4 - 6 %)
LOW (1 - 2 %)
County Rankings
% of county wooded
High
Med
Low
Bruce
Elgin, Grey
Huron
Lambton
Oxford
Perth
Middlesex
Kent
Essex
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
HURON
PERTH
MIDDLESEX
OXFORD
LAMBTON
KENT
ESSEX
LONDON
WINDSOR
Goderich
Stratford
Sarnia
Chatham
Woodstock
miles
kilometres
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and Lambton counties where approximately 28 to 37% of the total land area of these counties is devoted to bean production. Elgin was considered to have medium bean production (15%) while the counties of Middlesex, Huron and Perth were considered to have low production (5-8%). The remaining counties of Bruce, Grey and Oxford were reported as having no bean acreage.

3.2.3 TOTAL CORN

Figure 2 shows the distribution of total corn production. The corn statistics include acreages of grain and fodder corn. The format for data presentation is the same as Figure 1, except that the lowest class for corn is "very low". Oxford and Kent counties showed the highest corn production with approximately 38% and 35% of their respective total land area in corn production. Elgin, Middlesex, Huron and Perth counties were considered to have medium corn production (25-28%). Corn production in Lambton was lower (17%) and lowest (3-11%) in Grey, Bruce and Essex.

3.2.4 TILE DRAINAGE

The percentage of each county that is tile drained is shown on Figure 3. Kent and Lambton counties were most modified by agricultural drainage with 60 to 70% of the land area tile drained. Huron, Essex, Middlesex, Elgin and Perth counties exhibited medium tile drainage with approximately 38-51% of the land area tile drained. Oxford and Bruce had considerably less area tile drained (24 and 22%, respectively) while Grey had virtually no tile drainage (less than 2%).

3.2.5 PASTURE

Figure 4 shows the relative distribution of pasture land in the ten southwestern counties. Three class intervals were

used to show the distribution of this agricultural land use parameter, i.e., high, medium and low. The distribution of pasture is approximately opposite that observed for beans (Figure 1). The highest occurrence of pasture land is observed in Bruce and Grey counties (approx. 15 and 11%, respectively). The lowest pasture acreages (less than 2%) are found in Essex and Kent counties. The remaining counties have medium pasture acreages (3-7%).

3.2.6 WOODS

The distribution of wooded land is shown on Figure 5. Three class intervals were used to show relative differences for this land use. The highest percentages of woods (7-9%) occur in Bruce, Elgin, Grey and Huron counties. Lambton, Oxford, Perth and Middlesex counties are in the medium range (approx. 5-6%). The lowest occurrence of woods was observed for Kent and Essex counties (approx. 1-2%).

3.2.7 SUMMARY

Row crop production (beans plus corn) is greatest in the southwestern portion of the region and least in the north. Essex, Kent, Lambton, Middlesex and Elgin all have high percentages of the total land area in corn, beans or both. Bruce and Grey counties, on the other hand, have low or no land in row crops. The remaining counties have intermediate levels of row crop production. Tile drainage is also greatest in the south and least in the north. Wooded and pasture land uses are more prominent in the northern counties of the region, particularly Bruce and Grey counties, and least in the southwest, i.e., Essex and Kent.

3.3 WATER QUALITY CHARACTERISTICS

3.3.1 INTRODUCTION

The distribution of selected water quality parameters for the ten southwestern counties for the period 1980-1982 is shown in Figures 6 to 9. Water quality information was obtained from the Ministry's Provincial Water Quality Monitoring Network and analysed by GLAL. Mean concentrations were calculated for all stations in a county for the selected time period. The mean values were then grouped into two or three class intervals to enable comparisons of water quality on a relative scale. Mean county levels were chosen rather than plotting individual station means to enable comparisons with the land use information presented in Figures 1 to 5.

3.3.2 TOTAL PHOSPHORUS

Total phosphorus mean concentrations are depicted on Figure 6. This figure clearly shows that concentrations are highest in the southern counties and lowest in the northern counties. The highest mean concentrations occurred in Essex and Kent counties (0.380 and 0.330 mg/L, respectively). The lowest mean concentrations occurred in Huron, Bruce and Grey counties (.070, .040 and .020 mg/L, respectively). In Bruce and Grey counties several stations were observed to be below the Ministry guideline of 0.030 mg/L for total phosphorus. Mean concentrations range from .110 mg/L to .240 mg/L for the remaining five counties.

3.3.3 TOTAL NITROGEN

Mean total nitrogen concentrations appear on Figure 7. Only two groups of data are apparent for this water quality parameter; namely, low (Bruce and Grey) and high (all the rest). The mean concentrations for Bruce and Grey counties are 1.8 mg/L and 1.2 mg/L, respectively. The remaining counties range

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FIGURE 6

Relationships Between Land Use and Water Quality

Total Phosphorus Mean Concentration 1980/82

Mean Concentration of all Samples in a County

- HIGH (.330-.380 mg/L)
- MEDIUM (.110-240 mg/L)
- LOW (.020 - .070 mg/L)

County Rankings

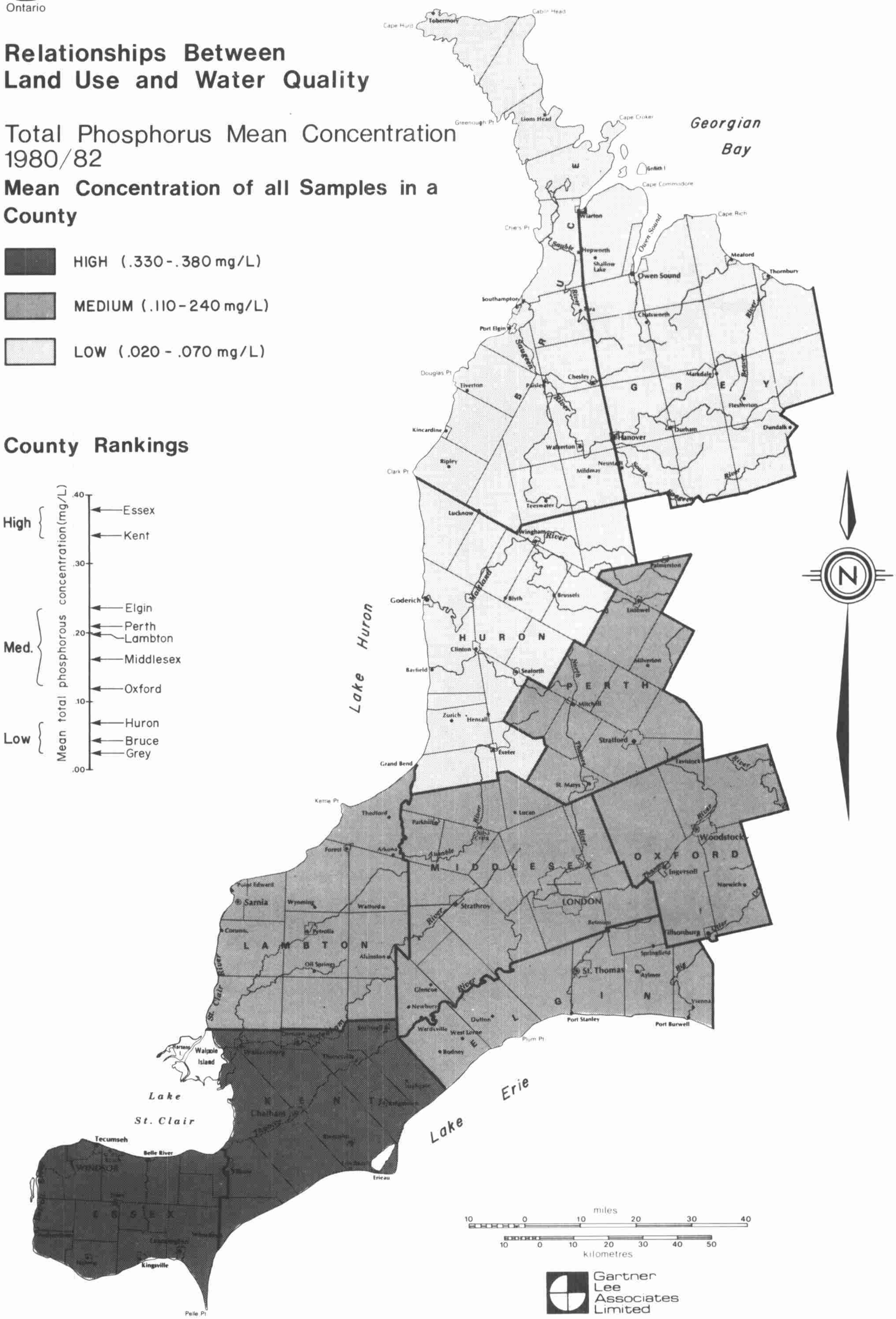

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FIGURE 7

Relationships Between Land Use and Water Quality

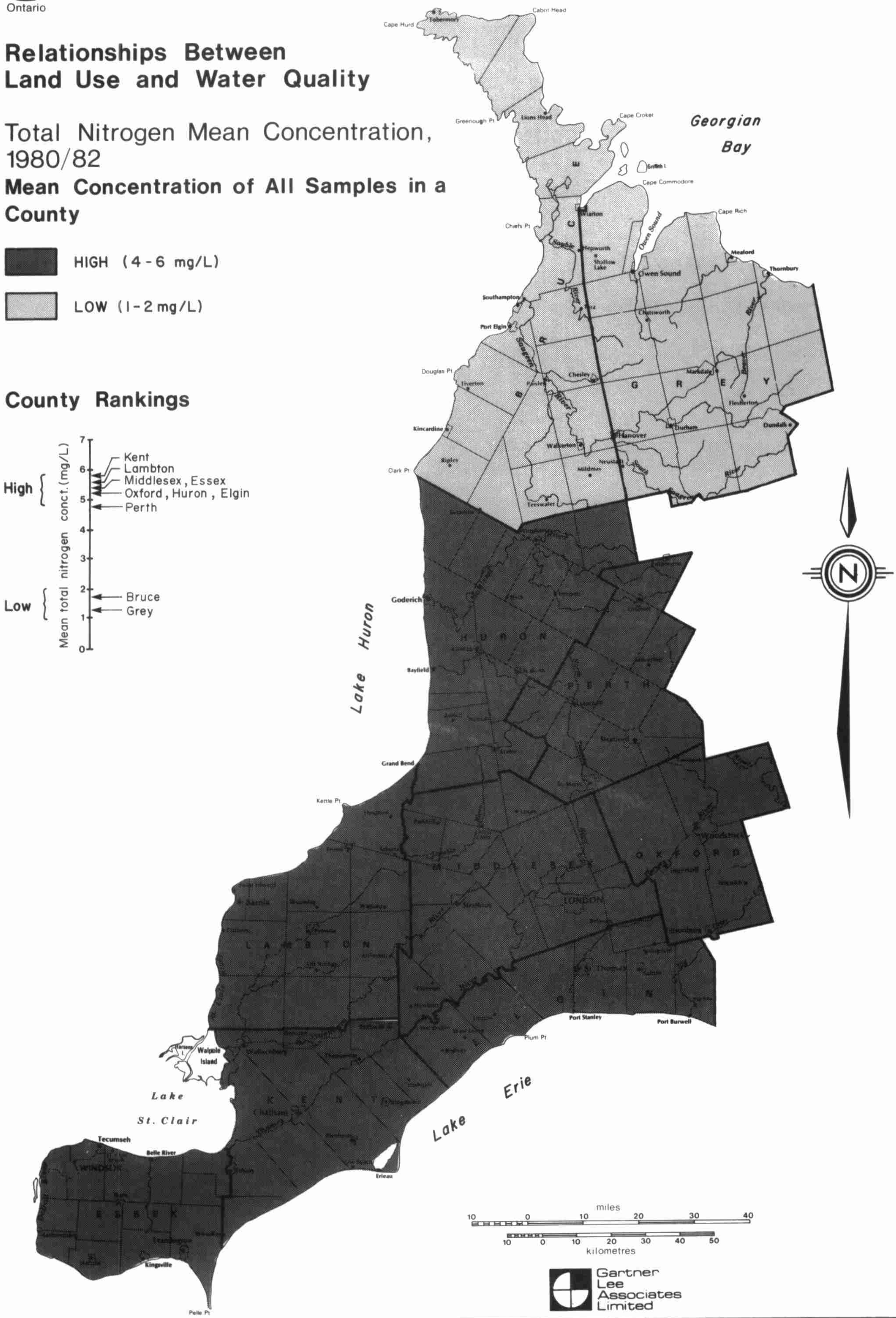
Total Nitrogen Mean Concentration, 1980/82

Mean Concentration of All Samples in a County

HIGH (4 - 6 mg/L)

LOW (1 - 2 mg/L)

County Rankings



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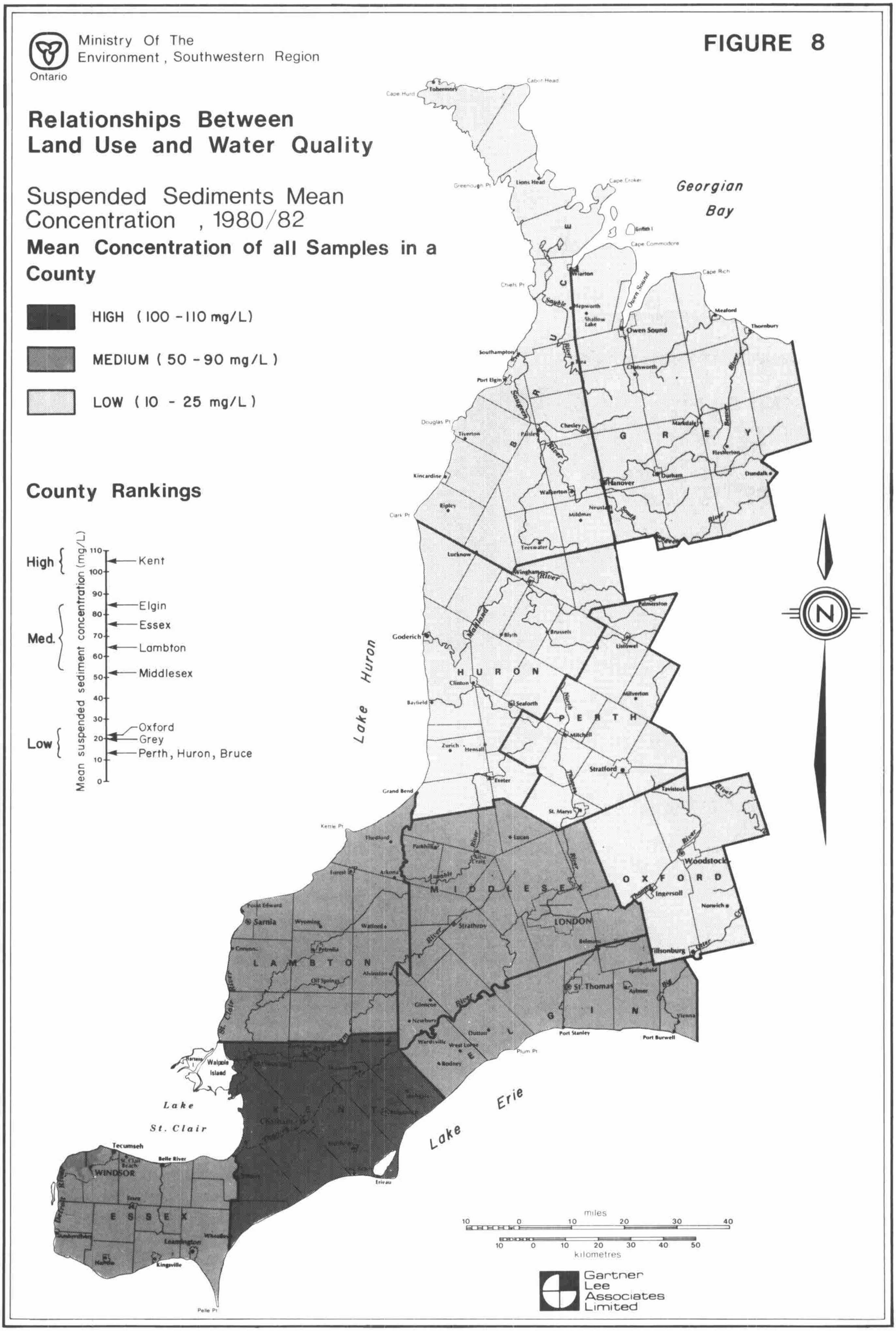
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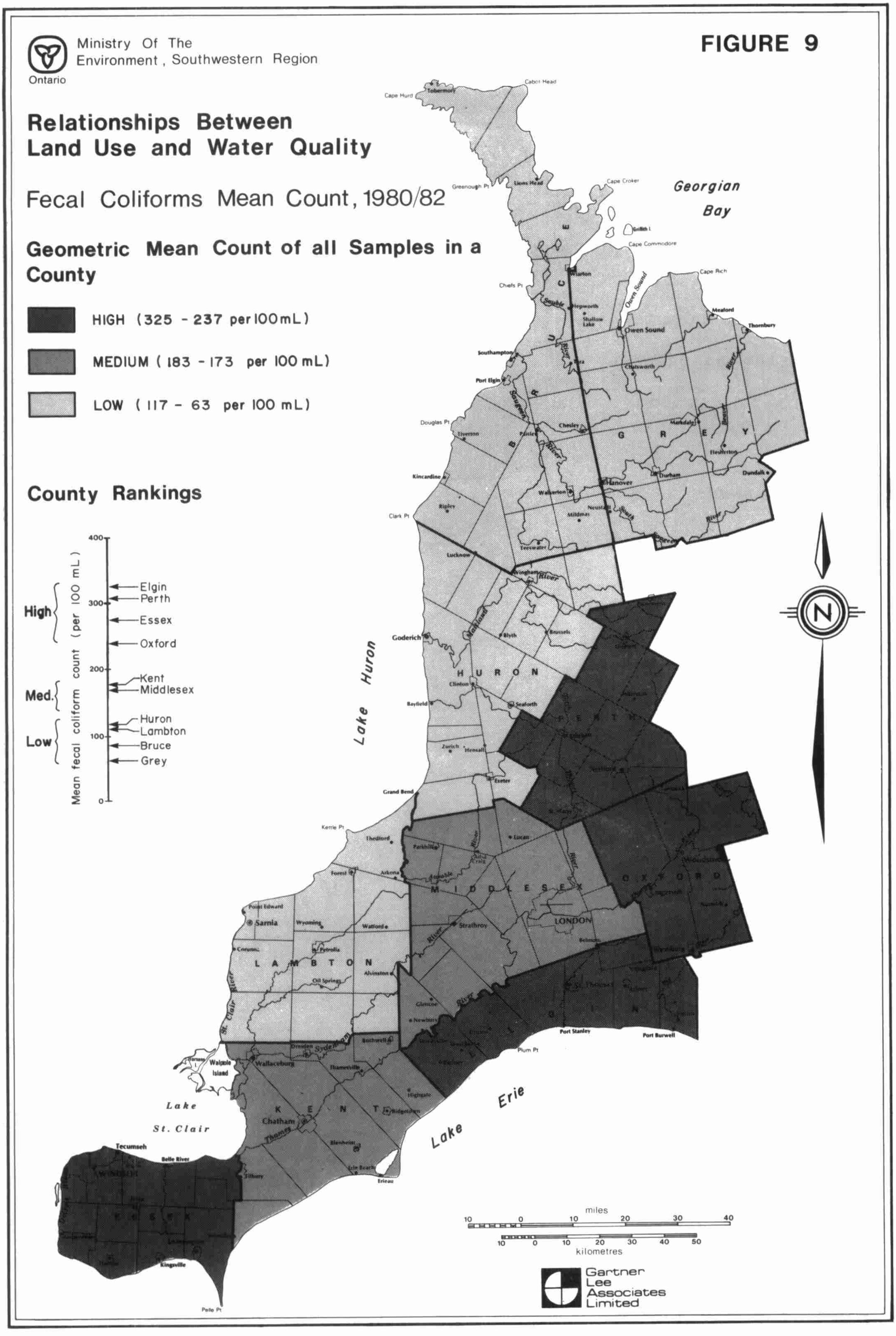
FIGURE 8
Relationships Between
Land Use and Water Quality
Suspended Sediments Mean
Concentration , 1980/82
Mean Concentration of all Samples in a County
HIGH (100 - 110 mg/L)
MEDIUM (50 - 90 mg/L)
LOW (10 - 25 mg/L)
County Rankings
High
Med.
Low
Mean suspended sediment concentration (mg/L)
110
100
90
80
70
60
50
40
30
20
10
0
Kent
Elgin
Essex
Lambton
Middlesex
Oxford
Grey
Perth, Huron, Bruce
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
BRUCE
GREY
HURON
PERTH
MIDDLESEX
OXFORD
LAMBTON
ELGIN
KENT
ESSEX
Owen Sound
Goderich
Stratford
LONDON
Woodstock
Sarnia
WINDSOR
miles
kilometres
Gartner Lee Associates Limited


Ministry Of The
Environment, Southwestern Region
Ontario
FIGURE 9
Relationships Between Land Use and Water Quality
Fecal Coliforms Mean Count, 1980/82
Geometric Mean Count of all Samples in a County
HIGH (325 - 237 per 100mL)
MEDIUM (183 - 173 per 100 mL)
LOW (117 - 63 per 100 mL)
County Rankings
Mean fecal coliform count (per 100 mL)
400
300
200
100
0
High
Med.
Low
Elgin
Perth
Essex
Oxford
Kent
Middlesex
Huron
Lambton
Bruce
Grey
Georgian Bay
Lake Huron
Lake St. Clair
Lake Erie
B R U C E
G R E Y
H U R O N
P E R T H
M I D D L E S E X
O X F O R D
L A M B T O N
K E N T
E S S E X
LONDON
Sarnia
Goderich
Owen Sound
Chatham
N
miles
10 0 10 20 30 40
kilometres
10 0 10 20 30 40 50
Gartner Lee Associates Limited

from 4.8 mg/L to 5.9 mg/L. As can be observed on the county rankings plot on Figure 7, no counties were observed to have mean concentrations between 2.0 mg/L and 4.5 mg/L.

3.3.4 SUSPENDED SOLIDS

Figure 8 shows the mean concentration of suspended solids for the ten counties in Southwestern Region. Once again it is clearly evident that the best water quality is found in the northern counties and the poorest in the southern counties. For suspended solids, the highest mean concentration was observed for Kent County (105 mg/L). The four counties bordering on Kent County had the next highest mean concentrations, ranging from 52 mg/L to 85 mg/L. The lowest observed mean concentrations occurred in Bruce, Huron, Perth, Grey and Oxford counties. The means ranged from 12 mg/L to 22 mg/L.

3.3.5 FECAL COLIFORMS

The mean fecal coliform count* for the ten counties in southwestern Ontario is shown on Figure 9. The spatial pattern for this parameter is somewhat different from that observed for the other parameter (Figures 6 to 8). The best water quality is observed to occur in Grey, Bruce, Lambton and Huron counties. The means ranged from approximately 60 counts/100 mL to approximately 110 counts/100 mL. This is the only water quality parameter for which Lambton County was classed as "low". The highest mean concentrations occurred in Elgin County (330 counts/100 mL).

3.3.6 SUMMARY

For the four parameters reported herein it appeared that water quality was generally best in the northern counties (primarily Bruce and Grey) and poorest in the southern counties (primarily Essex and Kent). For the remaining counties water

---

*Geometric Mean

quality generally appeared to be intermediate. For total nitrogen only two groups of data were apparent, i.e. low mean concentrations for Bruce and Grey counties and high mean concentrations for the remaining counties.

3.4 SPATIAL RELATIONSHIPS

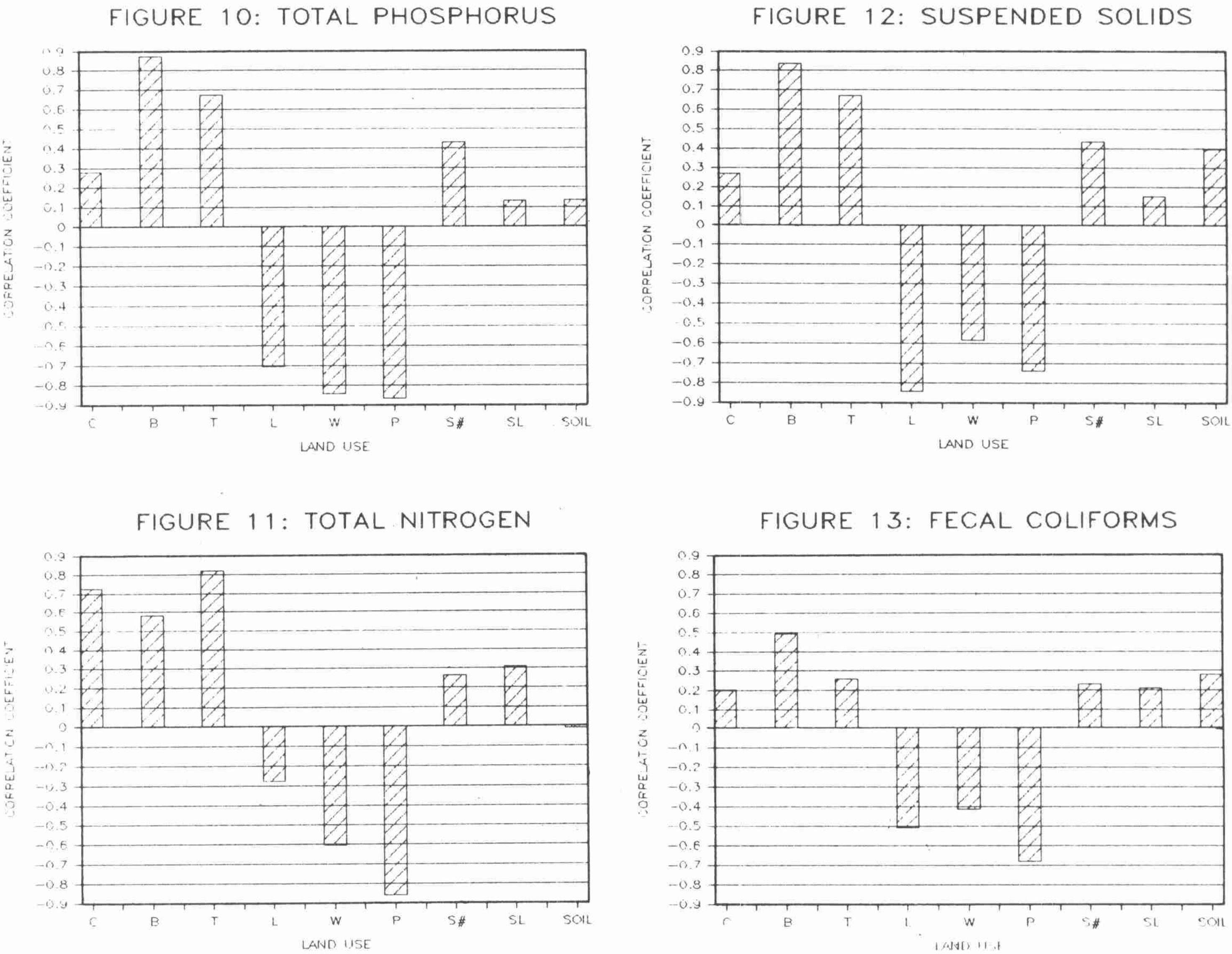
A first cut at identifying spatial relationships between land use and water quality was undertaken by visually comparing the land use spatial characteristics (Figures 1 to 5) to the water quality spatial characteristics (Figures 6 to 9) and noting apparent correlations. The summaries contained in Sections 3.2.7 and 3.3.6 were useful in attempting this qualitative correlation analysis.

Intensive row cropping patterns and poor water quality (total phosphorus, total nitrogen and suspended solids) appear to be related. The southern counties have the greatest row crop percentage and the poorest water quality whereas the northern counties have the least row crop percentages and the best water quality. Wooded and pasture land percentages also appear to be related to water quality, i.e. high percentage of woods and pasture and good water quality. Finally the distribution of tile drainage also appeared to be related to water quality. Tile drainage was greatest in the south (poor water quality) and least in the north (good water quality).

A second attempt was made to identify possible relationships between land use and water quality using simple linear regression analyses. These analyses were used only as a means to identify potential relationships and are not based on rigorous statistical procedures (see Section 2.4 on data limitations). The results of this analysis are shown on Figures 10 to 13.

Figure 10-13

Spatial Correlations Between Land Use and Water Quality



LEGEND

C - Corn Acreage
B - Bean Acreage
T - Tile Drainage
L - Livestock Intensity
W - Woodland
P - Pasture
S# - Number of STPs
SL - Hydraulic Loading of STPs
SOIL - Silt and Clay Textured Soils

The following land uses were included in the analysis:

- percent of county in corn
- percent of county in beans
- percent of county tiled
- total number of cattle
- percent of county in woods
- percent of county in pasture
- number of sewage treatment plants
- hydraulic loading of sewage treatment plants
- percent of county with silt and clay textured soils.

Figures 10 to 13 are bar graphs which enable a visual comparison of the land use parameters mentioned above and four water quality parameters. The Y-axis in each figure represents the correlation coefficient. A positive correlation coefficient indicates a direct relationship. The strength of the relationship is indicated by the magnitude of the coefficient. The larger the coefficient (to a maximum of 1 or -1) the better the relationship. The closer the coefficient is to 0 the weaker the relationship.

This analysis identified several relationships having correlation coefficients greater than 0.7. The correlations are listed on Table 2.

3.5 DISCUSSION OF RESULTS

The spatial characteristics of land use and water quality described in the previous sections are consistent with results of other studies reported in the literature. For example, Miller and Spires (11) found the highest farm land unit area loads for both total phosphorus and suspended sediment in Essex and Kent counties and the lowest in Grey and Bruce counties.

TABLE 2: SPATIAL RELATIONSHIPS

Total Phosphorus and	Beans	0.874
	Pasture	-0.865
	Woods	-0.841
	Livestock Intensity	-0.702
Total Nitrogen and	Pasture	-0.859
	Tile Drainage	0.821
	Corn	0.728
Suspended Solids and	Livestock Intensity	-0.839
	Beans	0.837
	Pasture	-0.736

Two Ministry of the Environment reports describe serious water quality problems in Rondeau Bay from agricultural soil erosion (12) and good water quality in the Beaver River, Grey County (10). These reports support the overview of poor water quality in the southern part of the Region and good water quality in the north.

A report on water quality using PWQMN data (12) found in general that stream water quality was closely linked with population density and intensity of agricultural activity. It reported that the sparsely populated northern part of the region tended to have good water quality whereas the more densely populated and intensively farmed southern part of the region had poor water quality. The pattern of total phosphorus and suspended solids mean annual concentrations being high in the south and low in the north is similar to the findings of this report.

An internal Ministry of the Environment report (13) presented a comparison of water quality data collected in the PWQMN to the Ministry of the Environment's water quality objectives. The report's finding that the Ministry guideline of 0.030 mg/L for total phosphorus was generally met only in the northern counties of the region agrees with the findings of the present report.

The correlation of total phosphorus with beans (row crops) was suggested by PLUARG (1). PLUARG also suggested a correlation of total phosphorus with silt and clay textured soils; however, this analysis did not confirm this finding. The inverse relationships of total phosphorus and pasture and woods is a reflection of the relationship of row crops, pasture and woods.

Increases in row crop production are often at the expense of pasture and woodland.

The relationship between total nitrogen and corn probably reflects soluble nitrates moving through tile drainage systems (see discussion on tile drainage in Section 4.4), whereas the relationship between corn and total nitrogen may reflect fertilizer applications.

The relationship between beans (row crops) and suspended solids has been noted by PLUARG (1) and other studies.

Similar correlations were noted for livestock intensity and pasture for most water quality variables. This is most likely due to the fact that these variables are not independent. For purposes of this report only pasture land was considered for further analysis.

4.0 TRENDS

4.1 INTRODUCTION

Land use and water quality trends in the Southwestern Region are presented in this chapter. Land use trends for beans, corn, tile drainage, pasture and woods were examined for the period 1966 to 1984. Certain land use data (e.g. woods and pasture) were available for census years, whereas beans and corn data were available on a yearly basis for the entire period 1966 to 1984. Water quality trends for total phosphorus, total nitrogen, suspended solids and fecal coliforms are presented for the period 1970 to 1982.

4.2 LAND USE

4.2.1 TOTAL BEANS

Land use trends for total beans for the ten southwestern counties are shown in Figure 14 (for census years only). Trends for selected counties are shown in Figures 15 to 17 (yearly values). Total beans consists of soya beans and dry white beans. Total beans are expressed as percent of total county area.

Bean acreages (% of county area) are insignificant in Bruce, Grey and Oxford counties. The most significant bean production occurs in Essex, Kent and Lambton counties, particularly in 1981 (see also Figure 1).

For all counties with significant bean production, the percent of county area devoted to bean production increased from 1966 to 1981. Very large increases are noted for Essex (Figure 15), Kent (Figure 16) and Lambton (Figure 17). The greatest increase occurred between 1976 and 1981.

4.2.2 TOTAL CORN

Figure 18 shows total corn trends for the ten counties in Southwestern Region for census years. Trends for selected counties are shown on Figures 19 to 23. Total corn consists of grain corn and fodder corn. Values shown are percentages of total county area devoted to total corn production.

Most counties (except Essex and Kent) show increasing trends. Huron County (Figure 19) is fairly typical. Approximately 7% of Huron was devoted to corn in 1966 compared to approximately 30% in 1984. Corn production in Kent County was quite variable from 1966 to 1984 (Figure 20).

FIGURE 14: LAND USE TRENDS - BEANS

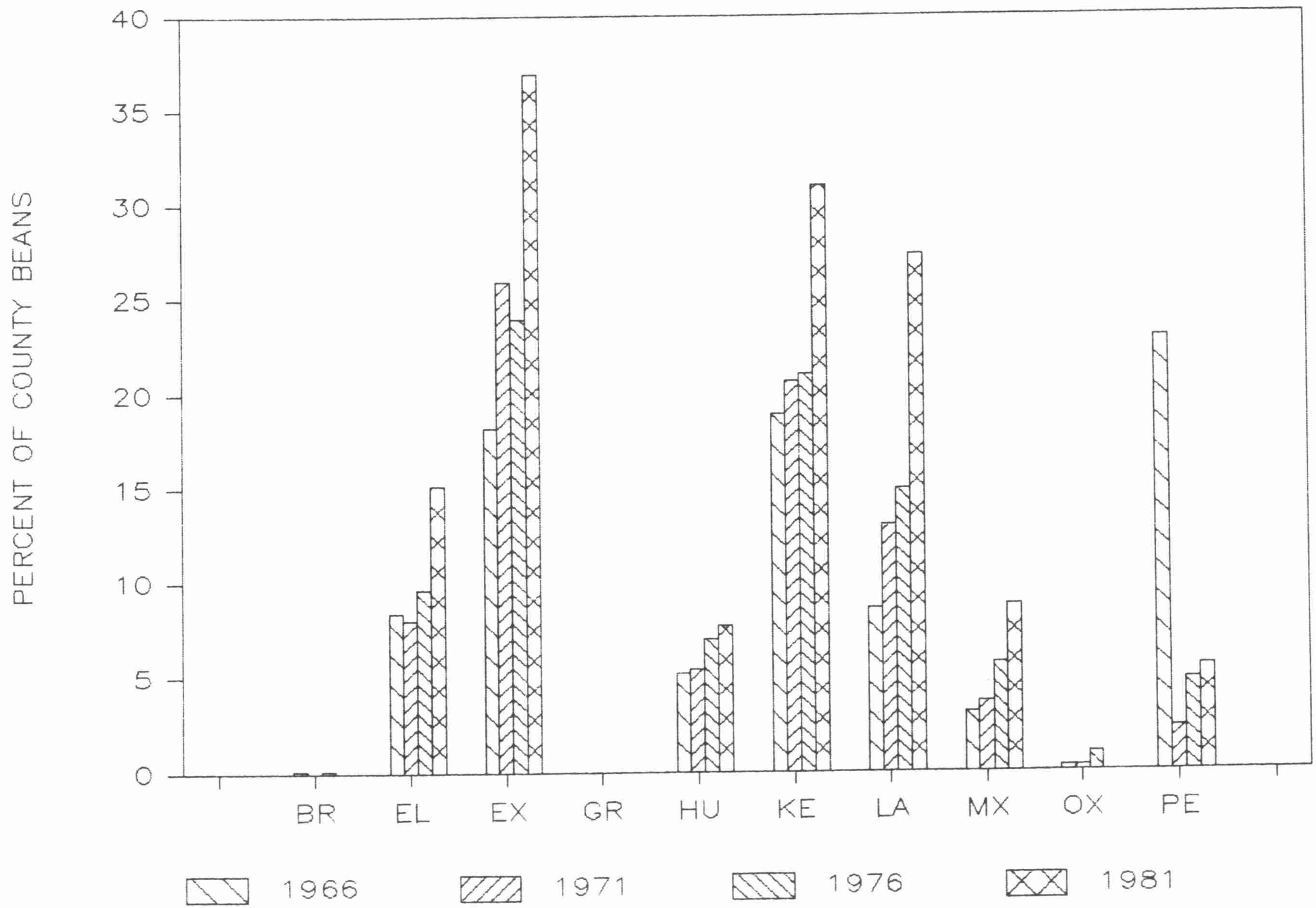


FIGURE 15: TOTAL BEANS GROWN — ESSEX

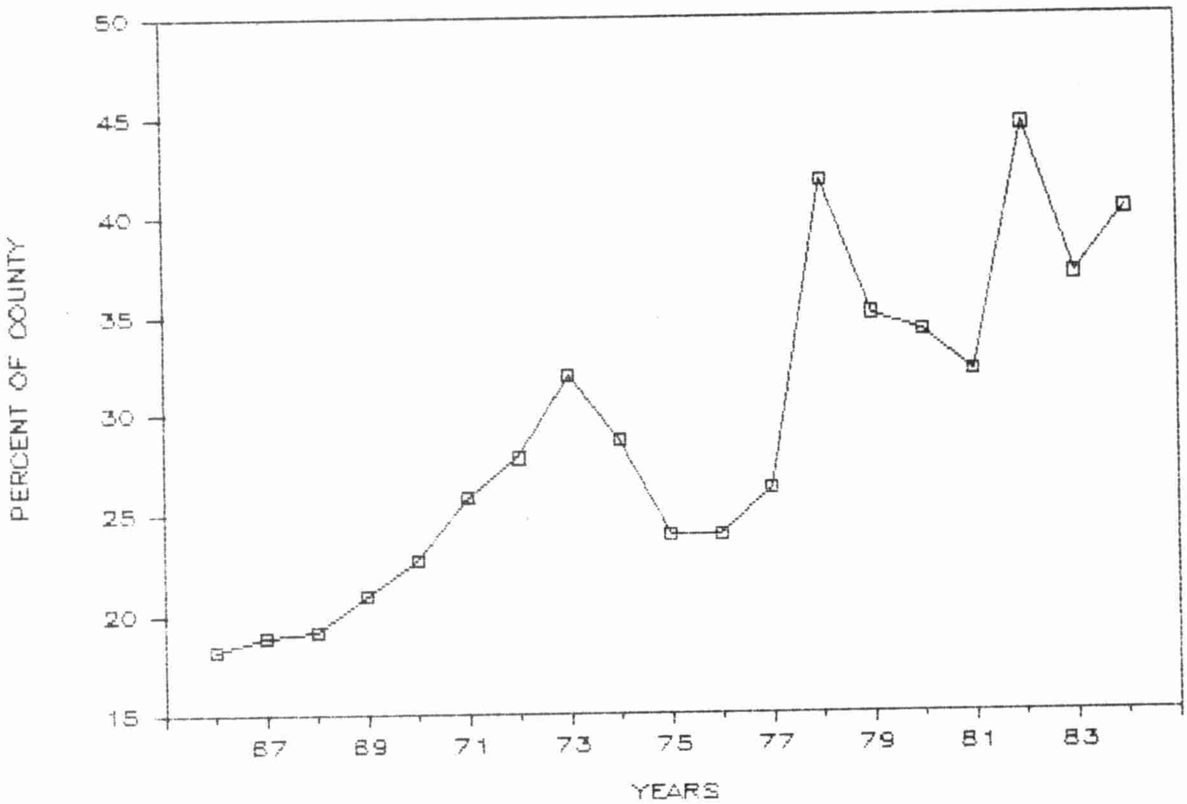


FIGURE 16: TOTAL BEANS GROWN - KENT

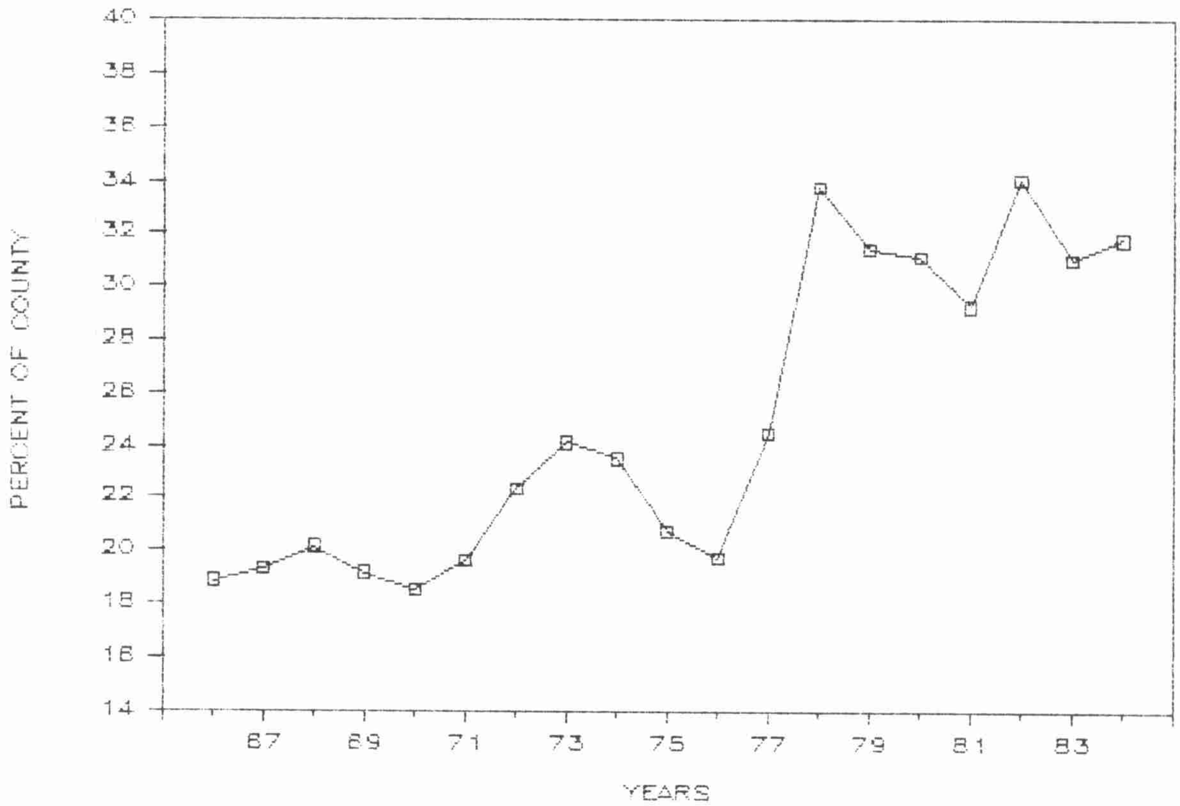


FIGURE 17: TOTAL BEANS GROWN – LAMBTON

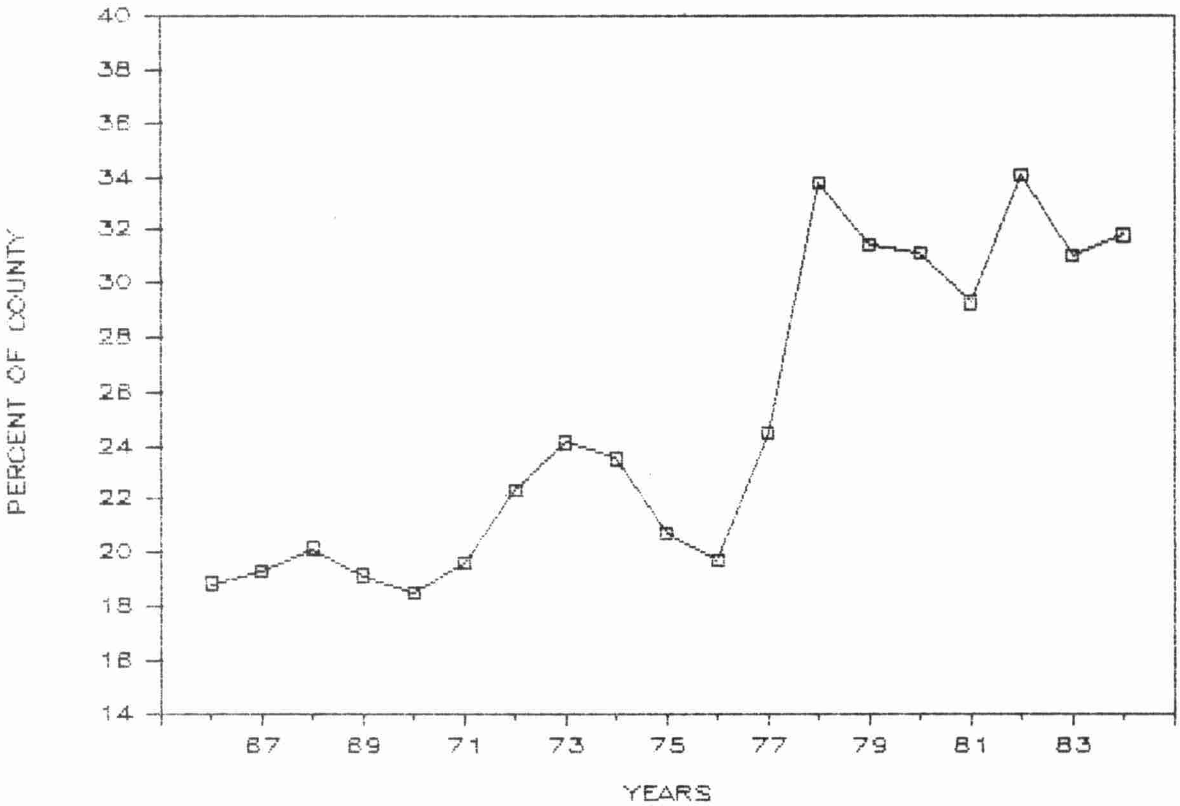


FIGURE 18: LAND USE TRENDS - CORN

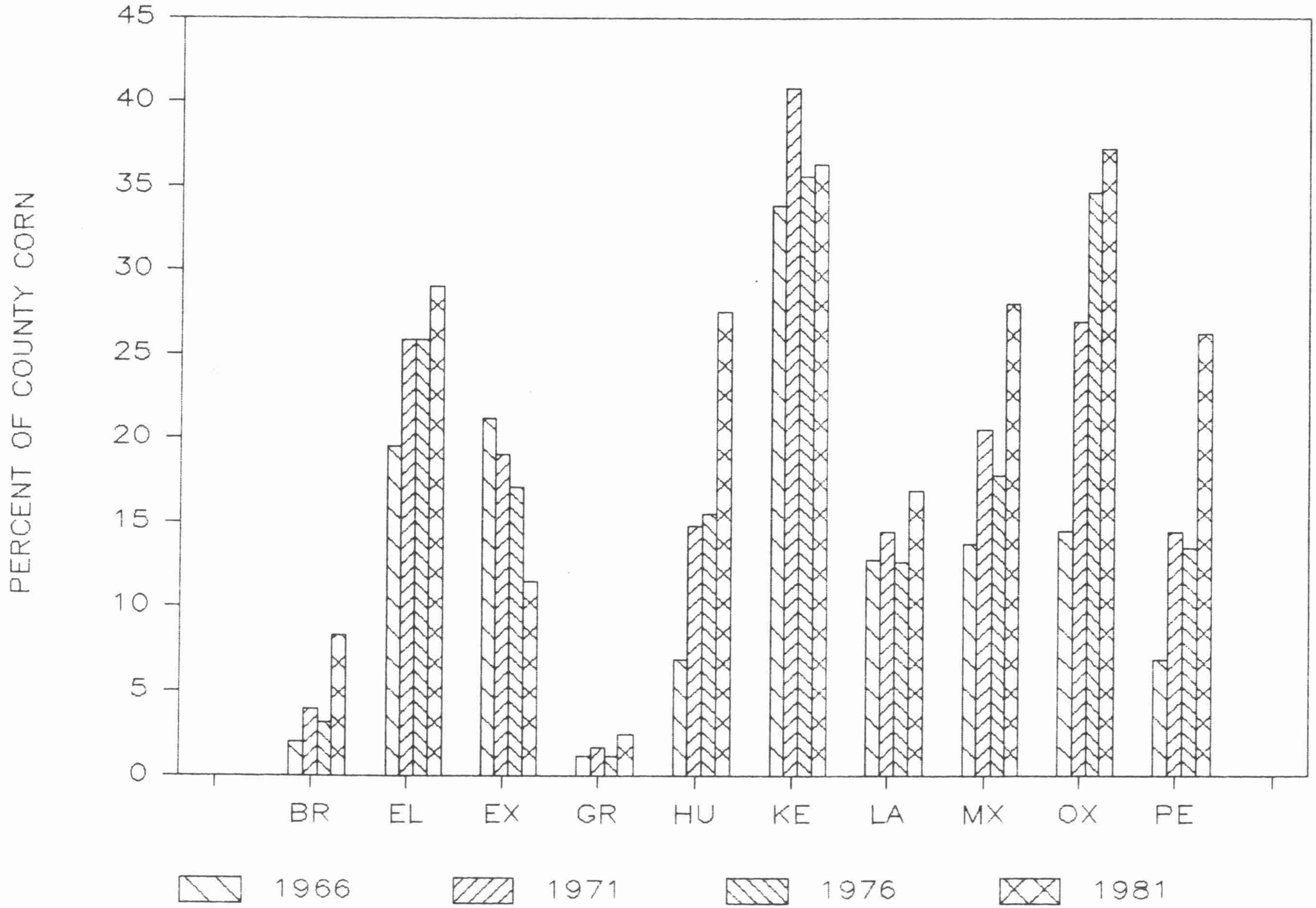


FIGURE 19: TOTAL CORN GROWN IN HURON

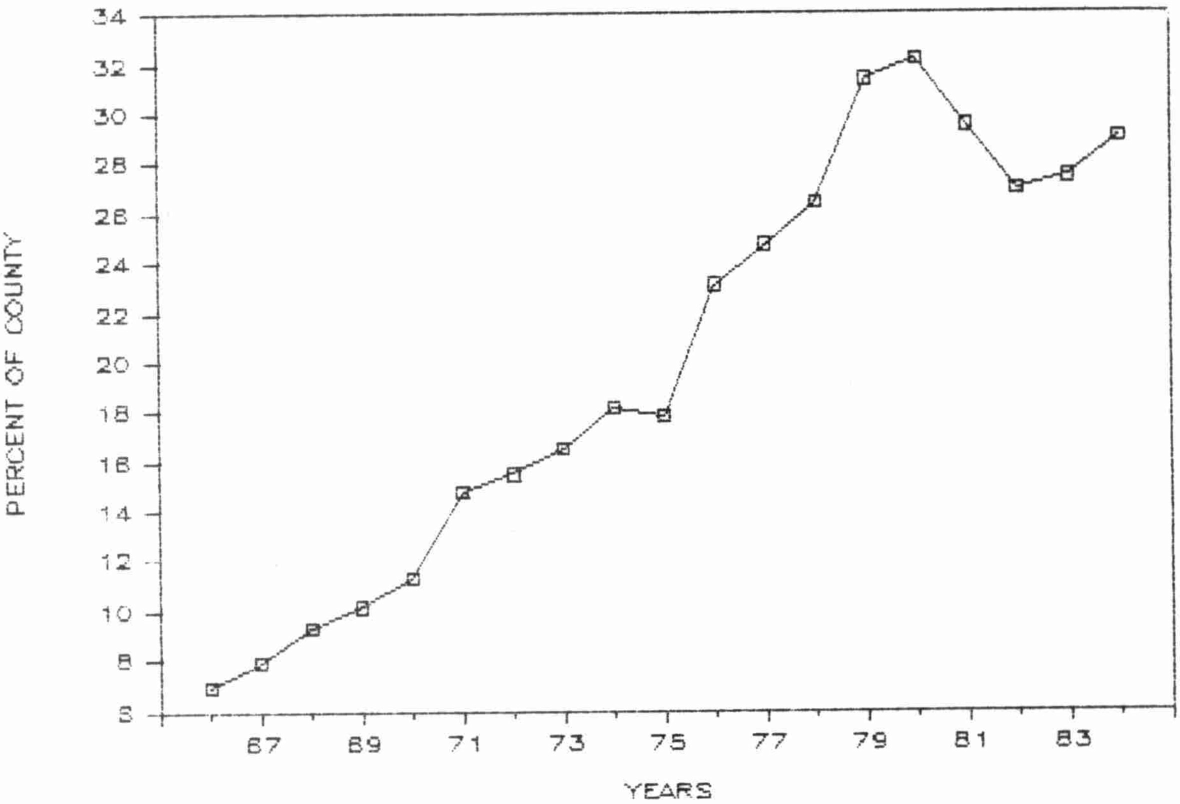


FIGURE 20: TOTAL CORN GROWN IN KENT

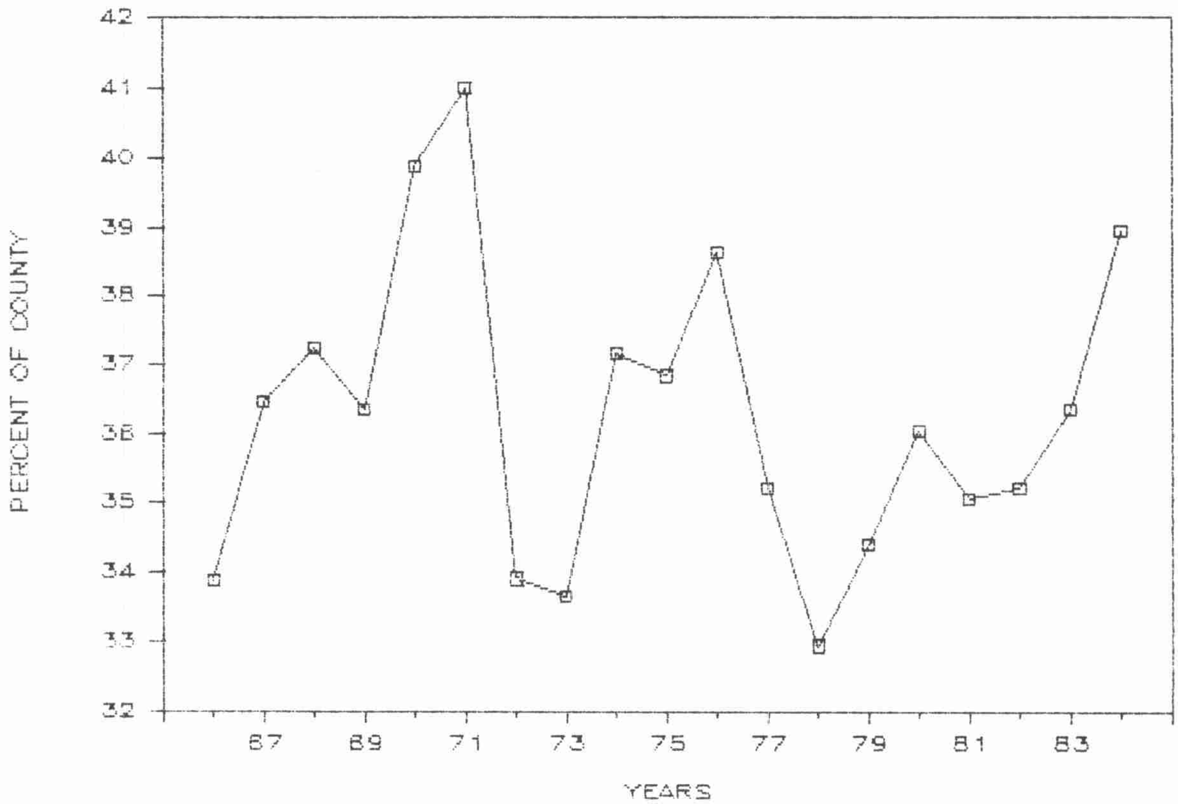


FIGURE 21: TOTAL CORN GROWN IN LAMBTON

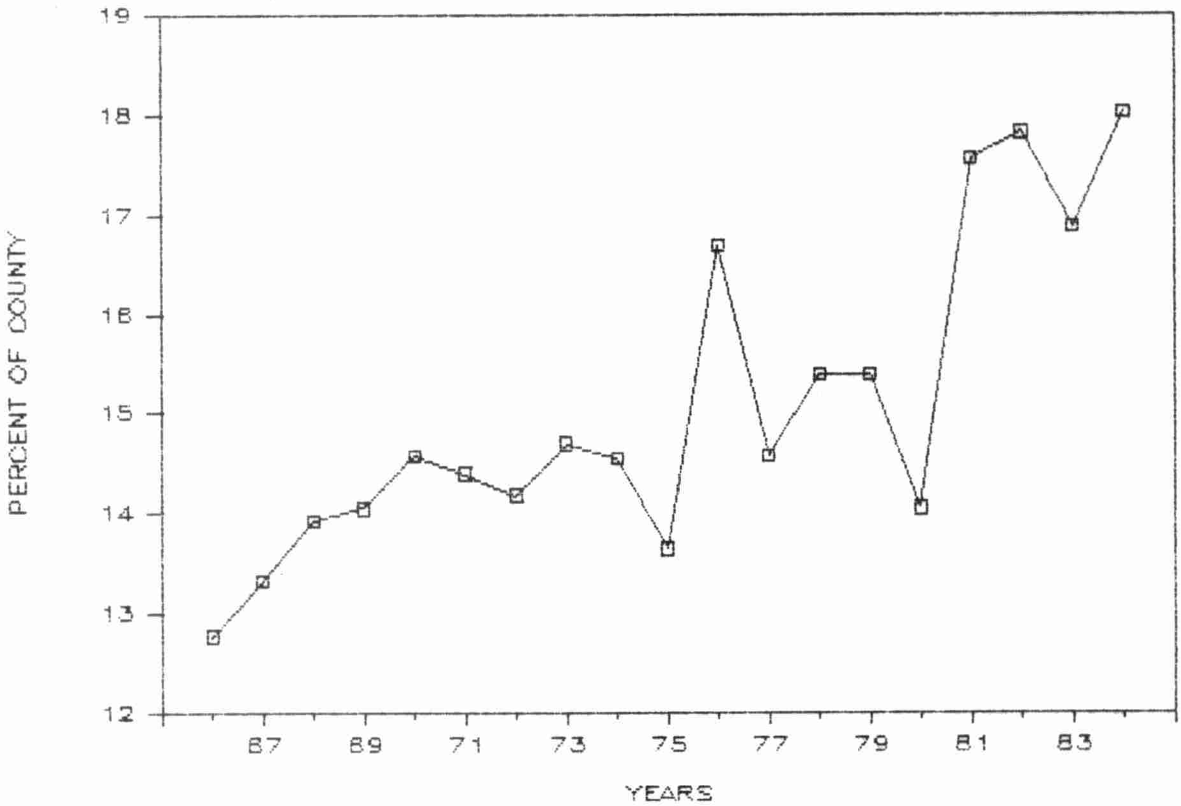


FIGURE 22: TOTAL CORN GROWN IN ESSEX

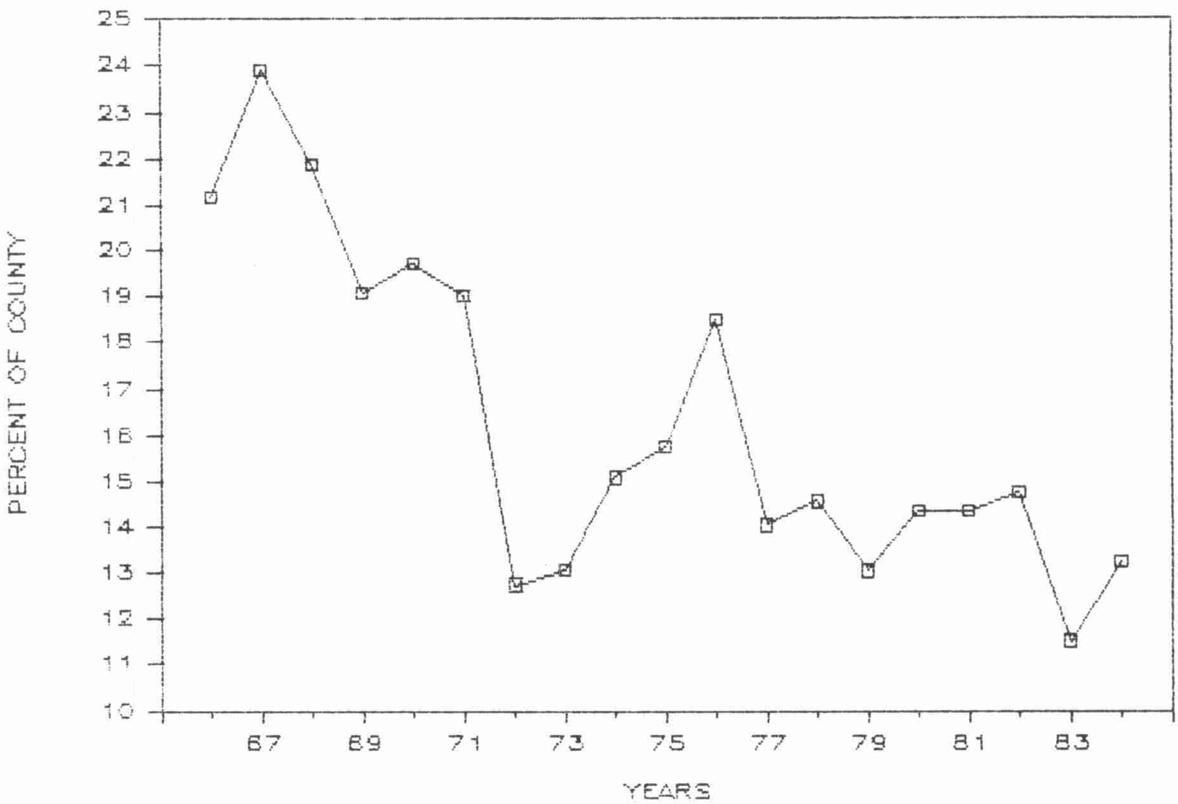
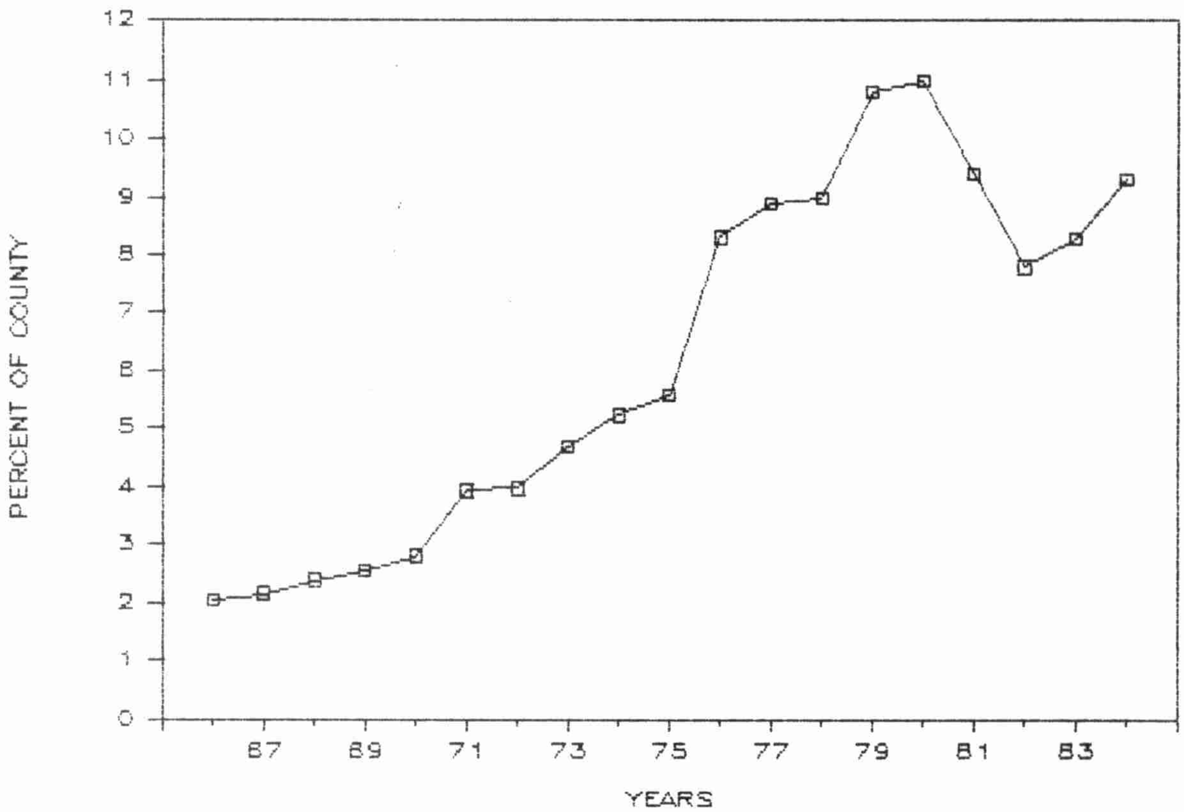


FIGURE 23: TOTAL CORN GROWN IN BRUCE



Total corn for Lambton (Figure 21) is also somewhat variable, however an increasing trend apppears to exist. Essex County shows a decrease in total corn (Figure 22). The percentage of the county devoted to corn production decreased from a high of 24% in 1967 to a low of about 12% in 1983. The greatest decrease occurred between 1971 and 1972.

Increasing trends of corn production also were observed in Bruce and Grey counties, however the magnitude was less. In Bruce (Figure 23) corn percentage increased from about 2% in 1966 to about 10% in 1981.

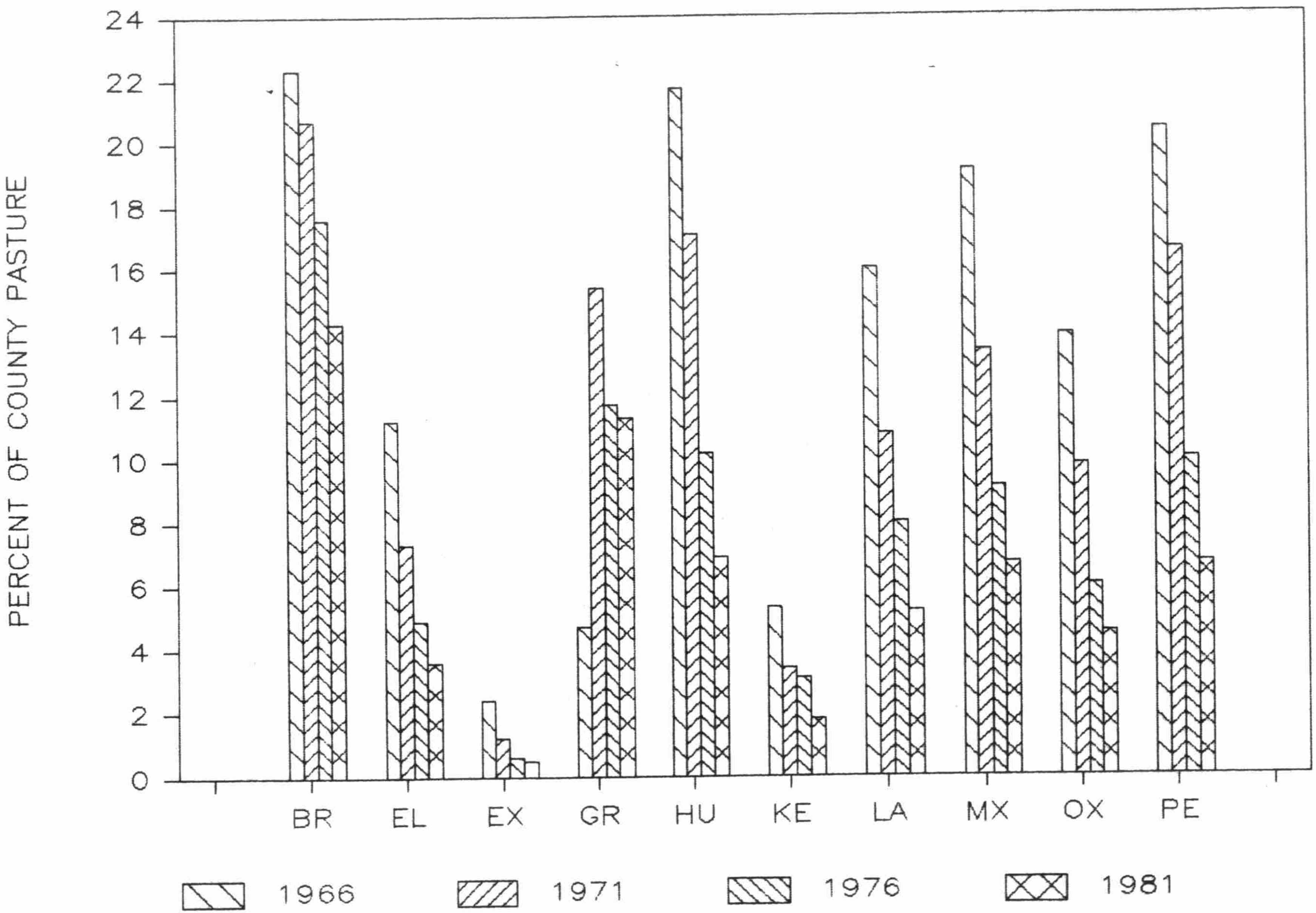
4.2.3 TILE DRAINAGE

No specific information on the actual acreages (or percentage of county) tiled were available. An attempt was made to estimate changes in tiled acreages using OMAF data on total annual debentures for tile drainage and estimates of tile cost/acre (14). An increase in the percentage of county area tiled (or tile drains improved) was noted for all counties. Generally the rate of increase was constant over the period studied (1972- 1982).

4.2.4 PASTURE

Trends in pasture land for census years is shown on Figure 24. Without exception a decrease in the percentage of county area devoted to pasture is observed. The greatest decreases are observed for Huron (approx. 8% from 1966 to 1981) and Perth (approx. 21% to approx. 7% for the same period). Pasture land is least in Essex and Kent counties.

FIGURE 24: LAND USE TRENDS – PASTURE



4.2.5 WOODS

Figure 25 shows trends in wood land for census years. In all counties the percentage of land area in woods decreased from 1966 to 1981. The greatest decrease occurred in Grey County (approx. 12% to approx. 8% from 1966 to 1981). Woodlands were least in Essex and Kent counties.

4.2.6 SUMMARY

Between 1966 and 1981 row crops (total corn and total beans) increased in most counties. In Elgin, Huron and Oxford counties both total beans and total corn increased. Total corn was somewhat more variable. During the same period, pasture and woodland acreages decreased continuously for all ten counties. The greatest decreases in pasture land occurred in Grey, Huron, Lambton, Middlesex and Perth counties. The greatest loss of woodland occurred in Grey and Bruce counties.

4.3 WATER QUALITY

4.3.1 INTRODUCTION

The mean annual concentrations of total phosphorus, total nitrogen, suspended solids and fecal coliforms for the period 1970 and 1982 were plotted for each county. An "ideal trend" line was then fitted by means of linear regression analysis. The slope of the trend line was then tested to see if it was significantly different from zero. Significance tests were performed at the 95% and 90% confidence levels.

The results of the analysis are summarized in Table 3 and discussed in the following sections.

FIGURE 25: LAND USE TRENDS — WOODS

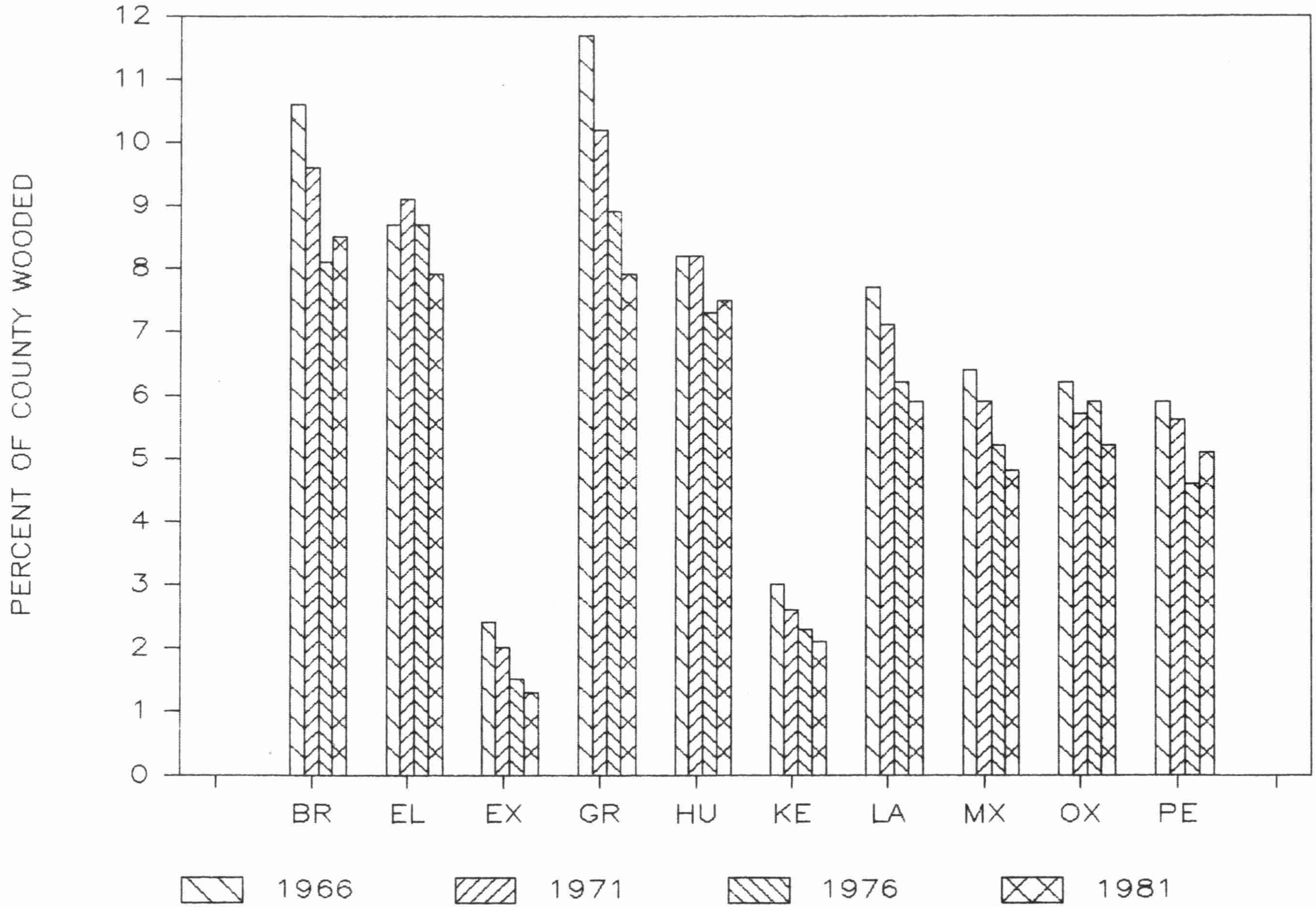


TABLE 3: SUMMARY OF WATER QUALITY TRENDS, 1970-1982

County	Total Phosphorus		Total Nitrogen		Suspended Solids		Fecal Coliforms	
	95%	90%	95%	90%	95%	90%	95%	90%
Bruce		-	+	+				
Elgin		-		+				
Essex	-	-						
Grey	-	-		+				-
Huron	-	-		+				
Kent	-	-	+	+				
Lambton	-	-		+			-	-
Middlesex			+	+				
Oxford	-	-		+				
Perth	-	-		+				

+ significant increasing trend
- significant decreasing trend
no significant trend apparent

4.3.2 TOTAL PHOSPHORUS

Table 3 indicates decreasing trends of total phosphorus for several counties. At the 95% confidence level significant decreasing trends were observed for seven counties, namely: Essex, Grey, Huron, Kent, Lambton, Oxford and Perth. At the 90% level all counties except Middlesex exhibited decreasing total phosphorus trends. Figures 26, 27, 28 and 29 are plots of mean annual total phosphorus concentrations for Essex, Huron, Oxford and Perth counties, respectively. The trends observed for these counties are typical of the other counties with decreasing trends.

4.3.3 TOTAL NITROGEN

Table 3 indicates increasing total nitrogen trends for most counties. At the 95% confidence level increasing trends were observed for Bruce (Figure 30), Kent (Figure 31) and Middlesex (Figure 32). At the 90% confidence level all counties except Essex exhibited significant increasing total nitrogen trends. The trends observed for Bruce, Kent and Middlesex are similar to those observed for the other counties with increasing trends.

4.3.4 SUSPENDED SOLIDS

The plots of mean annual concentration of suspended solids (contained in the appendix) indicates increasing trends for Bruce, Elgin, Middlesex and Oxford counties and decreasing trends for the remaining six counties. The trend analysis results reported in Table 3, however, identified no significant trends at either the 95% or 90% confidence levels.

FIGURE 26: TOTAL PHOSPHORUS TRENDS

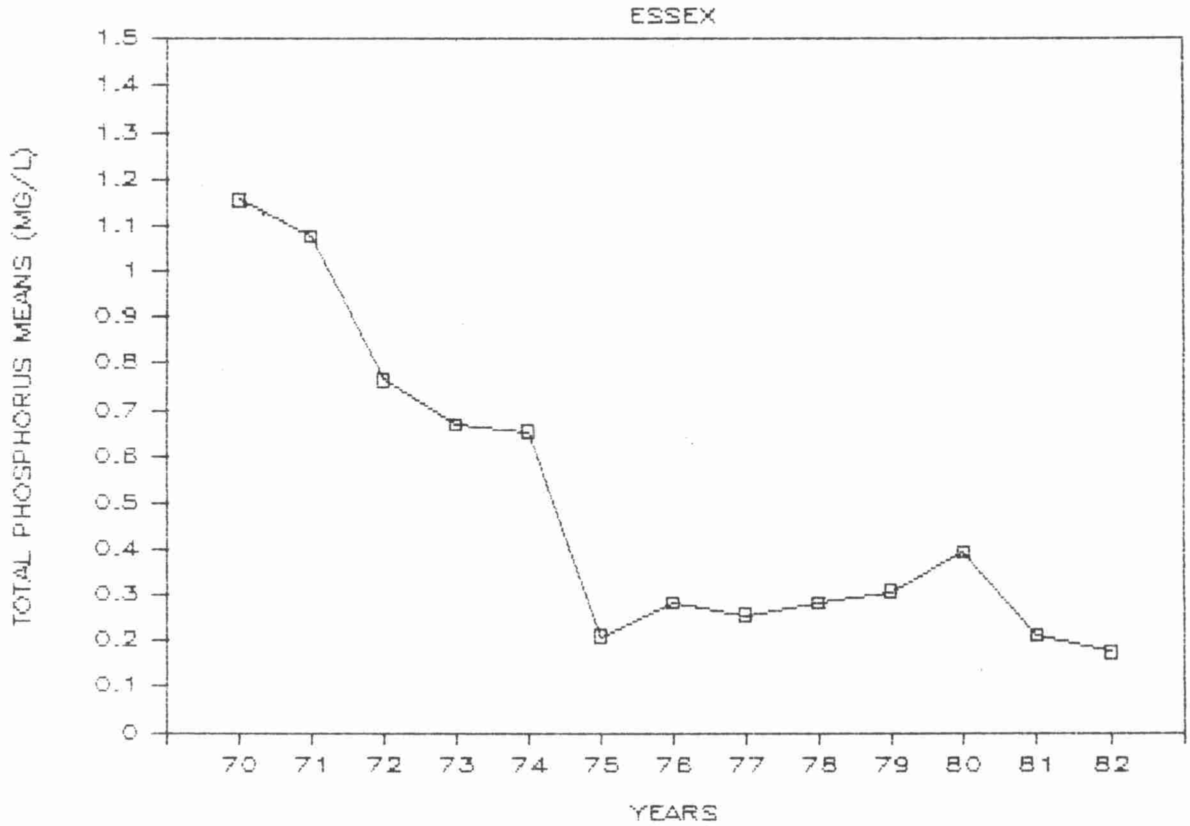


FIGURE 27: TOTAL PHOSPHORUS TRENDS

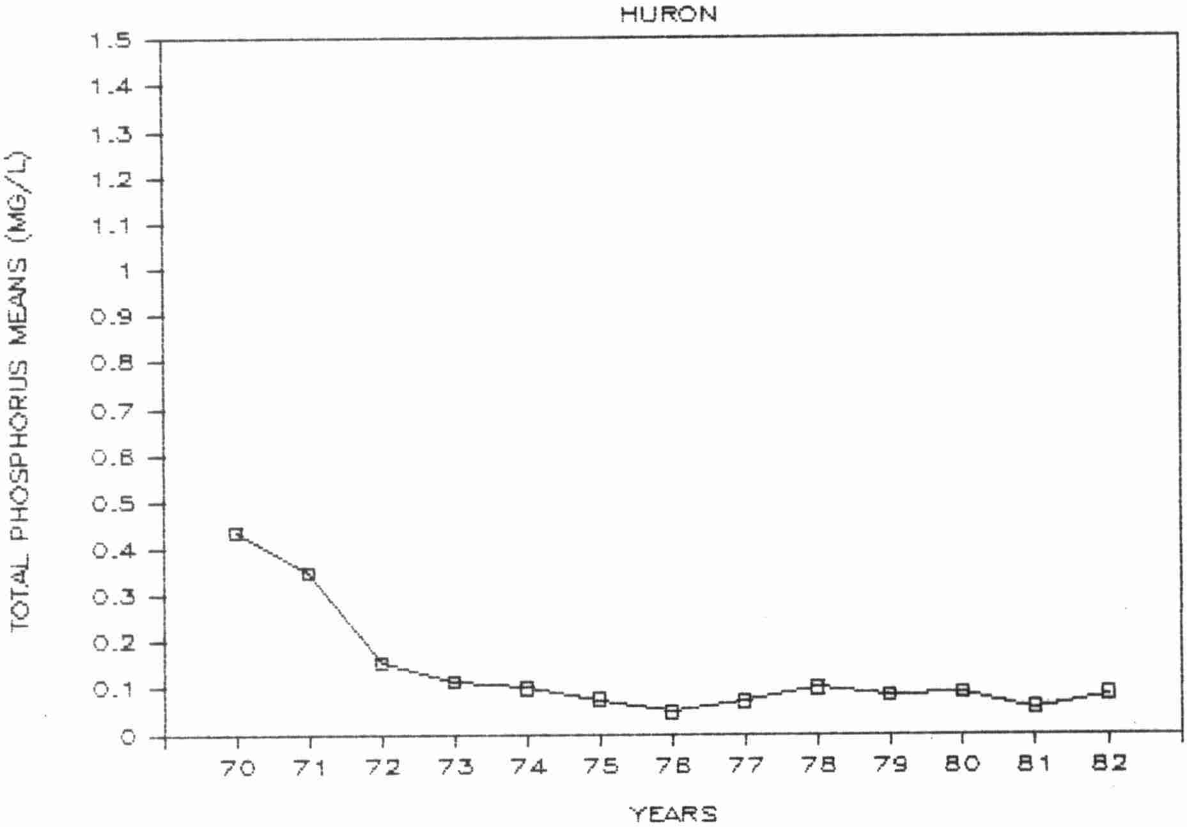


FIGURE 28: TOTAL PHOSPHORUS TRENDS

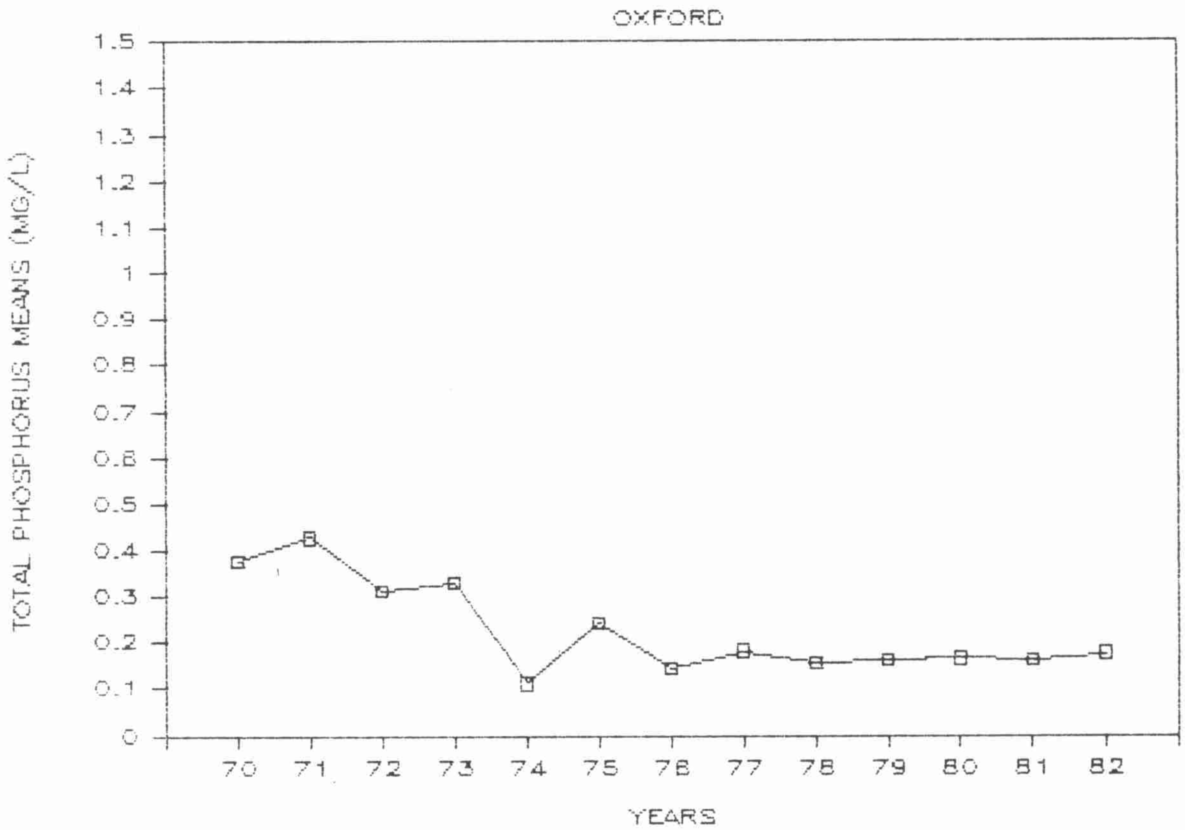


FIGURE 29: TOTAL PHOSPHORUS TRENDS

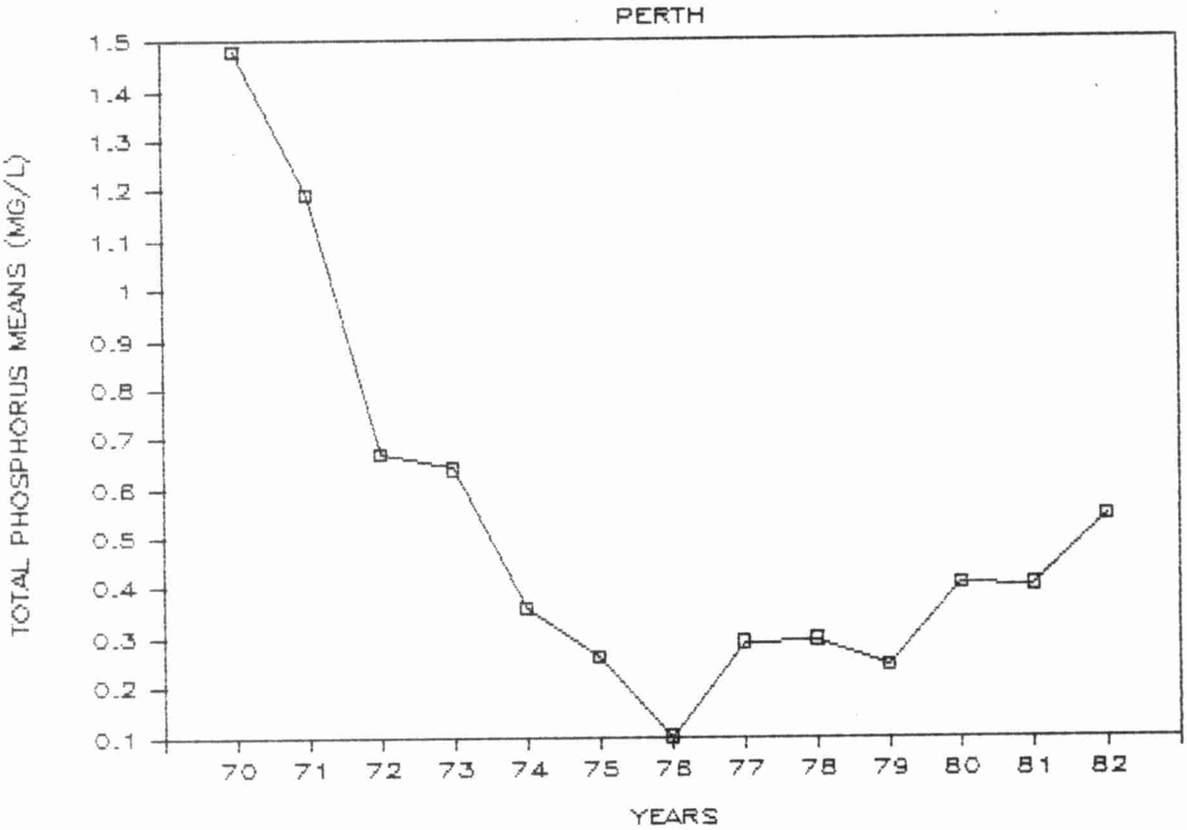


FIGURE 30: TOTAL NITROGEN TRENDS

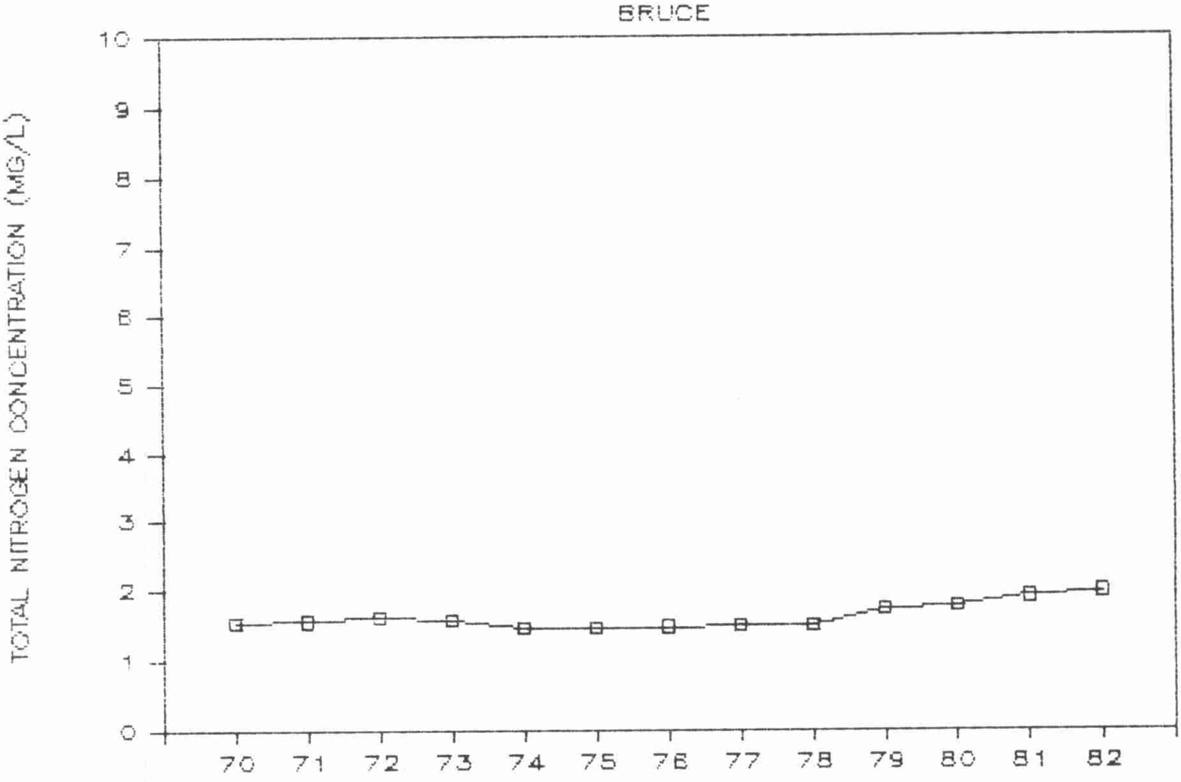


FIGURE 31: TOTAL NITROGEN TRENDS

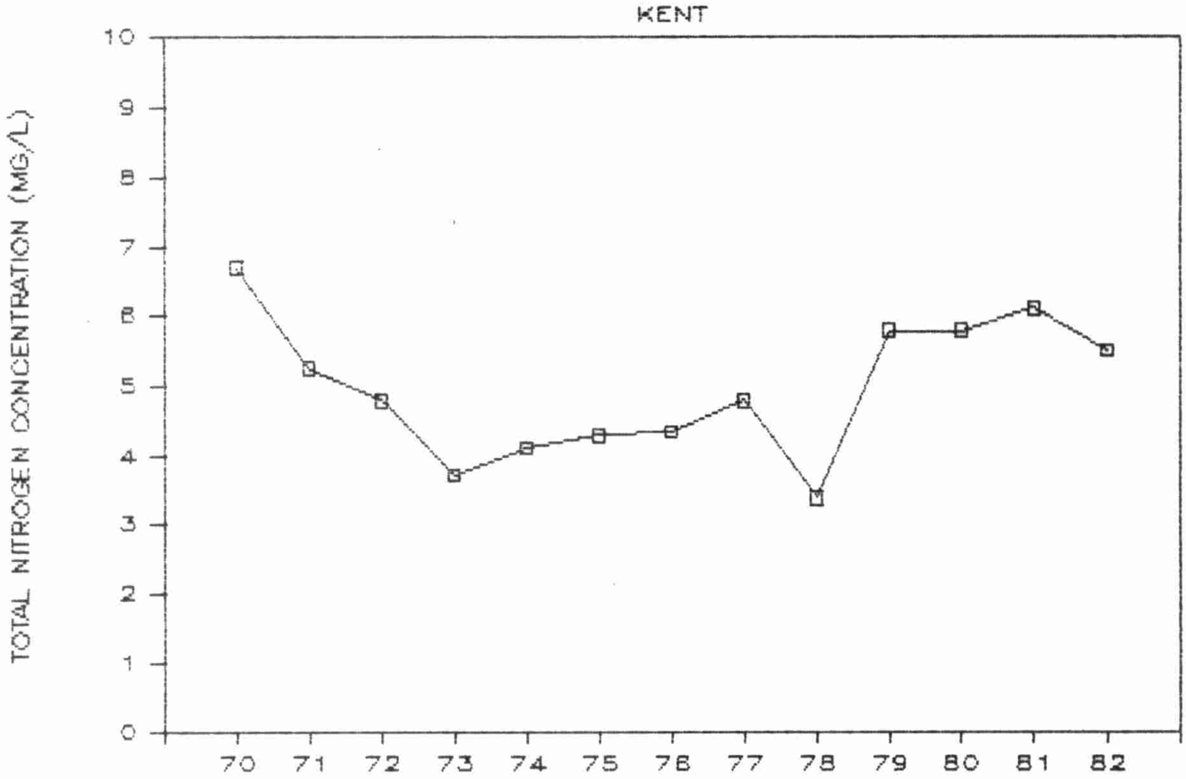
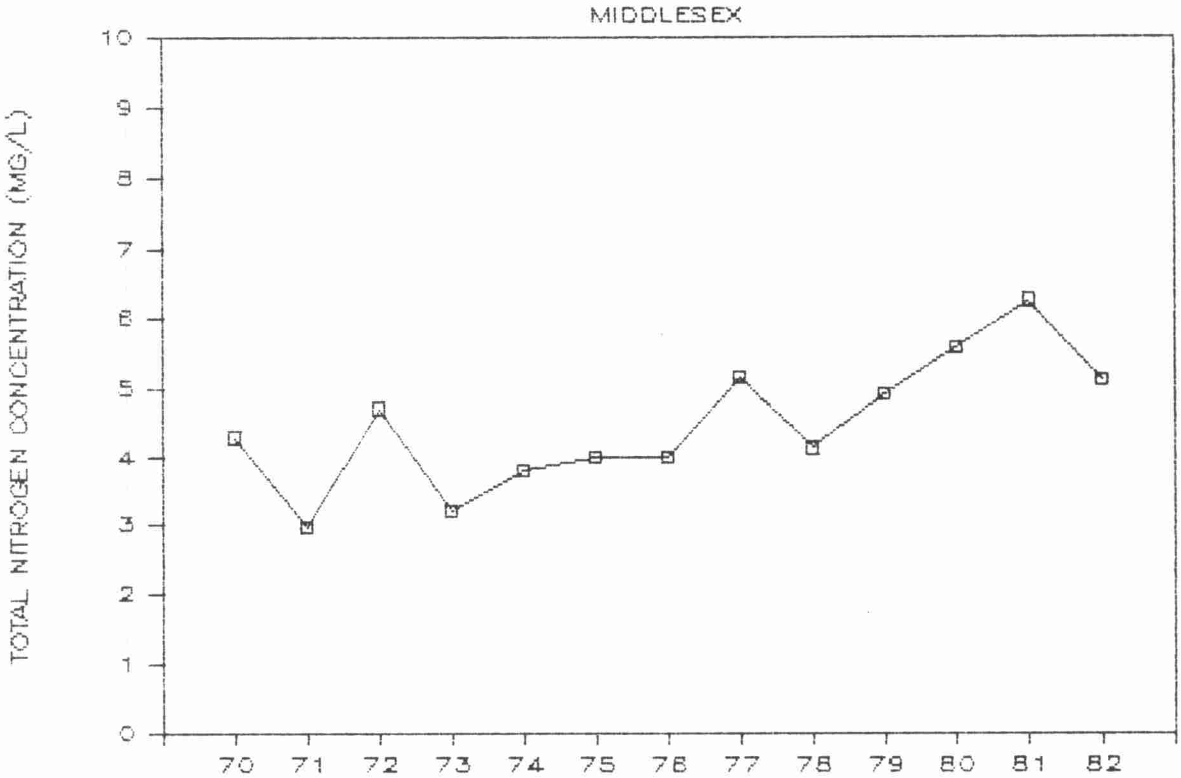


FIGURE 32: TOTAL NITROGEN TRENDS



4.3.5 FECAL COLIFORMS

The plots of mean annual fecal coliforms versus time indicated decreasing trends except for Kent County. The analysis (Table 3) identified only one trend significant at the 95% confidence level, namely, Lambton County and two at the 90% level, namely, Lambton and Grey counties.

4.3.6 SUMMARY

In general, improvements are apparent for total phosphorus while total nitrogen appears to be worsening. Trends for the remaining parameters are less obvious.

Observed improvements in total phosphorus mean annual concentrations over the 1970 to 1982 period are most likely due to improvements in water pollution control plant facilities and treatment processes and programs which removed phosphates from detergents. For most counties concentrations at the end of the study period were much lower than at the start, (see, for example, Figure 26).

Between 1972 and 1976 the substantial decreases in total phosphorus concentrations stop and from then on concentrations are generally lower and less variable. In some cases, increasing total phosphorus trends can be observed during the latter part of the study period (see, for example, Perth (Figure 29), Huron 1976-1982 (Figure 27) and Oxford 1978-1982 (Figure 28). These trends may be related to nonpoint source trends.

Deteriorating trends for total nitrogen were clearly apparent for all counties except Essex. Total nitrogen concentrations for Essex appeared to be generally high and quite variable over the study period.

Although total nitrogen concentrations are low in the northern counties increasing trends were identified. The trends in total nitrogen may be related to nonpoint source trends.

4.4 DISCUSSION OF RESULTS

The improving trend of total phosphorus over the period 1970 to 1982 is most likely due to the reduction of phosphorus in effluents from municipal water pollution control plants through improved treatment facilities and the reformulation of laundry detergents. An International Joint Commission Report (15) found declining trends in phosphorus in Lake Erie (since 1970) which were directly related to reductions in phosphorus loading from all external sources from 28,000t in 1968 to 12,350t in 1983. The loading reductions were in turn related to the reduction of phosphorus in effluents from municipal water pollution control plants through improved facilities and the reformulation of laundry detergent.

A Ministry of the Environment Report by Chin (16) examined trends at stations in the Provincial Water Quality Monitoring Network between 1964 and 1979. Chin's method of trend analysis involved use of a rating term that included seven water quality variables. Chin concluded that improvements in phosphorus concentrations at stations in the network were the result of reductions in phosphorus effluent from municipal water pollution control facilities.

Although substantial decreases in total phosphorus concentrations are evident during the early 1970's which can be attributed to the control of point sources, it is less clear whether or not nonpoint sources are adversely affecting total phosphorus concentrations. In some counties, (for example, Perth,

Figure 29), the mean annual phosphorus concentration has decreased from 1.480 mg/L in 1970 to 0.100 mg/L in 1976. After 1976 a less evident increasing trend is observed. However, this trend and similar ones for other counties were not found to be statistically significant.

The correlation of total phosphorus with total beans, pasture and woods (Section 3.4) and the observed trends for these land uses (Section 4.2) suggest that phosphorus concentrations should be increasing. There are several possible reasons why this analysis did not identify significant increasing total phosphorus trends in the late 1970s and early 1980s. These are:

1) The magnitude of the changes in concentration are much smaller for nonpoint sources in contrast to point sources. As a result trend analysis for the entire period 1970-1982 appears to be biased by the high values in the early 1970s.

2) Although increasing total phosphorus trends are apparent after 1976 (generally) they were not found to be statistically significant. The lack of data (6 years) is a major reason for this.

3) Other factors such as stream flow and fertilizer application rates have not been taken into account that may effect the trend analysis.

The correlation of total nitrogen with pasture, tile drainage and corn (Section 3.4) and the observed trends for these land uses (Section 4.2) all suggest that total nitrogen

concentrations in Southwestern Region should be increasing. This indeed seems to be occurring. Studies reported in the literature generally support this finding and provide insight as to why it is occurring.

In an Ohio study, Baker (17) noted high nitrate-N concentrations in southwestern Ohio streams and suggested that increased conservation tillage practices could increase nitrate contamination in streams. Baker also reported that total nitrogen losses in the Sandusky Basin via streamflow were equivalent to about 43% of the fertilizer inputs and about 16% of the overall total nitrogen inputs.

R.R. Lowrance, et. al. (18) reported on a study of nutrient cycling in agricultural wastersheds with regards to streamflow and artificial drainage. Concentrations of Nitrate-N were found to be much higher in drainage water than in streamflow. Loading of Nitrate-N from drained row-cropped fields was found to be 60 times the unit area loading from mixed cover watersheds. Nitrate-N showed distinct seasonal trends in streamflow with decreases in spring and summer. Nitrate-N constituted 95% of the total Nitrogen measured in drainage waters.

Although no significant suspended solids trends were observed at the county level several studies have reported on severe agricultural related erosion. The report Cropland Soil Erosion, Estimated Cost to Agriculture (19) prepared by the Ontario Institute of Pedology provided an estimate of the cost of soil erosion to agriculture. High losses were reported in Kent, Elgin, Middlesex, Oxford and Huron counties.

A 1981 study by the Ministry of the Environment (20) identified a significant decline in the general ecology of Rondeau Bay. This study concluded that severe sheet erosion from the adjoining intensively farmed lands was fouling the Bay with suspended sediments. In response to this report and a general concern for the serious soil erosion problems occurring in the Rondeau Bay Watershed a master erosion control plan was developed for the watershed (3). The report presented several recommendations for remedial measures to reduce the soil erosion problem.

The trends for fecal coliform are difficult to interpret due in large part to the data limitations outlined in Section 2.4 and the fact that the specified analysis did not identify any significant correlations with land use (Section 3.4). The literature suggests a link between fecal coliform pollution and livestock feedlot operations, manure spills and manure spreading (9). Bacteriological contamination in urban runoff was also identified as a significant source (2).

A Ministry of the Environment report (4) presented findings on the factors affecting microbiological water quality in Lake Huron Beaches. This study found that the majority of fecal bacterial loading to the Lake Huron beaches came from agricultural areas. The primary routes for bacteria entry to streams were thought to be:

1. barnyard surface runoff;
2. barnyard manure seepage into tile drains;
3. cattle access to creeks and streams;
4. erosion of manure - spread fields; and,
5. manure spills.

Finally, the Ministry of the Environment, Southwestern Region (21) has identified manure spills to streams as a short-term but severe pollution problem that can result in fish kills.

4.5 OTHER POLLUTION SOURCES AND TRENDS

As noted in the introduction (Section 1.3) this study is intended to provide an overview of water quality and land use (particularly agriculture) in southwestern Ontario. The overview nature of the study limited the data analysis to a manageable number of water quality and land use parameters. Only significant findings have been included in this report.

Obviously the factors affecting water quality in southwestern Ontario are far more complicated than the simple relationships presented here. Furthermore, there are a number of other factors and pollutant sources which affect water quality. The following section is intended to touch briefly upon these other factors.

4.5.1 URBAN LAND USE

Diffuse urban land use has also been identified as a significant (but less wide spread) source of contamination to watersheds. O'Neill, (22) found total phosphorus, metals (lead, copper, chromium), chloride, organic chemicals and bacteria contamination arising from urban land uses. The control of surface runoff from streets appeared to be significant in reducing nonpoint urban pollution.

In comparing the estimated contributions of urban and agricultural diffuse sources to Lake Erie (both United States and Canada), PLUARG (1) found that 68% of the total diffuse load was a result of agriculture and 21% from urban land use.

4.5.2 PESTICIDES

PLUARG (1) found contamination of streams and rivers from some previously used pesticides. More recent studies have found increased pesticides usage and occurrence in streams. A report, Survey of Pesticide Use in Ontario, 1983, (23) found that the pesticide active ingredients used in the Canadian Lake Erie basin increased to 3632 t in 1983 from 2534 t in 1978 (approx. 43% increase). The same report found at least 0.2 kg/ha of triazine herbicide was applied in all counties in southern Ontario in 1983. The heaviest use of phenoxy herbicides (more than 0.1 kg/ha) was in Oxford, Huron and Perth counties (for Southwestern Region). Applications of herbicides other than triazine or phenoxy types exceeded 0.7 kg/ha for Elgin, Essex, Kent, Lambton, Middlesex and Oxford. Insecticide usage was greatest in Essex, Kent, Middlesex, and Oxford (more than 0.1 kg/ha). Fungicide usage was greatest in Essex and Kent (more than 0.1 kg/ha). The application of nematocides was greatest in Elgin county (over 1.0 kg/ha).

Under typical conditions only 1% to 2% of applied herbicides move off individual fields; however, Wauchope (24) reported that where heavy rains immediately follow pesticide application as much as 10% of some herbicides can be lost.

In general, the study of the transport of herbicide into streams rivers and lakes has received little study. The Ministry of the Environment (25) is currently involved in a study of atrazine modelling in a small agricultural watershed in Southwestern Region.

4.5.3 FERTILIZERS

A main finding of PLUARG (1) was that total phosphorus loads were related to material usage, soil type and land use intensity. A PLUARG report (26) concluded that applications of fertilizers, manure and livestock operations adjacent to streams were contributing dissolved phosphorus and nitrogen to streams. The practice of applying more fertilizer phosphorus to row crops than would be recommended for soil tests was observed in the PLUARG test watersheds. This practice was thought to increase phosphorus concentrations in streams.

4.5.4 METALS

PLUARG (1) and other studies (22, 2) identified urban areas as sources of metal contamination to streams. Other than naturally occurring levels, agriculture has not been identified as a source of metal pollution (1). Another PLUARG report (27) identified elevated levels of copper in streams in the Saugeen River basin. The report concluded that these levels were naturally occurring.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The conclusions of this study are presented in two sections. Sections 5.1.1. presents conclusions concerning spatial chartacteristics and relationships presented in chapter 3.0. Section 5.1.2 presents conclusions of the trend analysis contained in chapter 4.0.

5.1.1 SPATIAL CHARACTERISTICS AND RELATIONSHIPS

Following are the general conclusions drawn from the findings presented in chapter 3.0.

1. For the four parameters studied (i.e.,total phosphorus, total nitrogen, suspended solids and fecal coliforms), water quality during the period 1980-1982 was generally best in the northern counties (primarily Bruce and Grey) and poorest in the southern counties primarily (Essex and Kent).

   The following specific findings are noteworthy:

   - Ministry of the Environment guidelines for total phosphorus (0.030 mg/L) were achieved at the majority of stations in Bruce and Grey counties and the northern part of Huron County. Exceedence of total phosphorus guidelines was greatest in Essex and Kent counties where the 1980-1982 mean concentrations were 0.380 mg/L and 0.330 mg/L respectively. These levels are approximately ten times the Ministry's guideline.

   - Two distinct data groupings were noted for total nitrogen. Bruce and Grey counties had very low total nitrogen mean (1980-1982) concentrations (i.e. 1.8 mg/L and 1.2 mg/L respectively. Total nitrogen mean concentrations elsewhere were much higher, (i.e. 4.8 mg/L to 5.9 mg/L).

   - Suspended solids mean concentrations were found to be highest in Kent County (105 mg/L) and lowest in Bruce, Huron, Perth, Grey and Oxford counties (12 mg/L to 22 mg/L).

   - The best water quality with respect to fecal coliform occurred in Grey, Bruce, Huron and Lambton counties (i.e. 60 counts/100 mL to 110 counts/100 mL). The highest mean concentrations occurred in Elgin County (1750 counts/100 mL).

2. Intensive agricultural activities in 1981 were found to be the greatest in the southwestern portion of the region and least in the north. The following specific findings are noteworthy:

   - Row crop productions (beans plus corn) was greatest in Essex, Kent, Lambton, Middlesex and Elgin counties. Bruce and Elgin counties had low or no land in row crops.

   - Tile drainage was greatest in the southern counties and very low in Bruce and Grey counties.

   - Wooded and pasture land uses were most prominent in the northern counties, particularly Bruce and Grey counties, and least in the southwest, i.e. Essex and Kent counties.

3. Linear regression analysis on 1980 to 1982 water quality and 1981 land use data identified the following spatial relationships:

   - total phosphorus and beans (+)
pasture (-)
woods (-)

   - total nitrogen and pasture (-)
tile drainage (+)
corn (+)

   - suspended solids and beans (+)
pasture (-)

   - fecal coliform (none identified)

(+) indicates a positive correlation greater than 0.7
(-) indicates a negative correlation greater than 0.7

5.1.2 TRENDS

Following are the general conclusions concerning water quality and land use trend analysis presented in chapter 4.0. The conclusions are grouped according to water quality variables.

5.1.2.1 Total Phosphorus

1. Improving trends for total phosphorus (mean annual concentrations) occurred in all counties except Middlesex for the period 1970 - 1982. The primary reason for this improving trend appears to be the reduction of phosphorus loadings from water pollution control plants in the early 1970s.

2. The spatial analysis (Section 3.4) found correlations of total phosphorus with total beans (+), pasture (-) and woods (-). The observed trends for these land use parameters presented in Section 4.2 (i.e. increasing beans, decreasing woods and pasture) suggests that total phosphorus concentrations should be increasing. Although some evidence of increased phosphorus concentrations in the late 1970s was found it was not statistically significant.

5.1.2.2 Total Nitrogen

1. Deteriorating trends for total nitrogen (mean annual concentration) occurred in all counties except Essex. The reason for the observed deteriorating trends appears to be related to intensive agricultural activity. The spatial analysis (Section 3.4) found total nitrogen correlated with pasture (-), tile drainage (+) and corn (+). The observed trends for those land use activities (or features) presented in Section 4.2 (i.e. decreasing pasture,

increasing tile drainage and increasing corn) suggests that total nitrogen concentrations should be increasing. Other studies reported in the literature and discussed in Section 4.4 support this finding.

5.1.2.3 Suspended Solids and Fecal Coliforms

Although severe problems with suspended solids and fecal coliforms have occurred at numerous locations in the region, no significant relationships between water quality and land use were identified at this level of analysis.

5.2 RECOMMENDATIONS

5.2.1. INTRODUCTION

The study has used the results of the provincial water quality monitoring program to confirm the general pattern of poor water quality in the south and good water quality in the north. Existing water quality conditions in the region have been tentatively linked with distribution of row cropping, tile drainage, woods and pasture land. The study has found increasing trends of total nitrogen in most southwestern counties that appear to be related to increased corn production, increased tile drainage and a decline of pasture and wood land.

The possible degradation of good water quality in Bruce and Grey counties is of particular concern, trends towards greater agricultural activity in these counties could lead to water quality degradation. Increases in total nitrogen are already apparent.

Although water quality in the southern counties is already considerably degraded it is hoped that this condition can be prevented from worsening.

A number of remedial practices are available to combat pollution from nonpoint sources. The report of the Nonpoint Source Control Task Force (5) contains an overview of the most successful control measures and practices. The Task Force concluded that agricultural nonpoint sources are controllable and at much less expense than previously thought. It appears that many controls can be put in place through voluntary acceptance by farm operators. This in fact has been demonstrated in many programs such as those carried out by the Thames River Implementation Committee, Stratford Avon River and Rondeau Studies. The key to success appears to be to secure continued provincial and federal support of demonstration projects and delivery programs.

A major problem in nonpoint source control identified by the Task Force was the lack of a co-ordinated and comprehensive program to address the problem. This now appears to be solved by the development of a comprehensive management program by federal and provincial agencies. The primary objective is to achieve the target phosphorus loading reductions stipulated in the 1978 Great Lakes Water Quality Agreement and Annexes. An added benefit will be the improvement of water quality in streams in Southwestern Region, not only for total phosphorus but for other water quality parameters as well.

The following recommendations are presented to assist the Ministry in its effort to protect and enhance the surface water resources in Southwestern Region.

5.2.2. MANAGEMENT PRACTICES AND PROGRAMS

It is recommended that staff of the Southwestern Region continue and perhaps even increase, their awareness and participation in nonpoint source programs, and research at all levels.

A great deal of activity is currently under way in the field of nonpoint source pollution. Much of this activity is focussed on phosphorus reduction in view of the targets established by the 1978 Great Lakes Water Quality Agreement.

Obviously the Region is concerned with many parameters other than phosphorus. Increasing trends in total nitrogen identified in this report, fecal coliform contamination and pesticides are examples of regional concerns.

While it is recognized that the workload of regional staff is not conducive to extensive participation in committees, etc., it is strongly recommended that technical staff participate as much as possible in International, Federal and Interministerial committees addressing nonpoint source issues. Their continued participation will ensure that local knowledge, expertise and concerns are brought to bear on the problem.

<u>It is recommended that nonpoint source control efforts be focussed on problem areas</u>.

Many studies in Canada and the United States have established the fact that pollution problems may occur in only a small percent of a drainage basin. An example of this would be severe erosion on steeply sloping land. Obviously specific control measures should be targetted towards these problem areas. The directing of funds to selected areas (or farmers) to control a problem may seem simple, but unfortunately implementation of targetted programs is not easy. To ensure fair and effective targetting of resources criteria for selection of critical areas should be established.

It is recommended that the Region's participation in, and support of, watershed management studies continue, and if possible, increase.

Watershed management and specific studies such as SAREMP (2), Rondeau (3) and Pittock (9) have provided critical data on the extent and nature of specific pollution problems. These studies investigate problems at a level of detail beyond routine monitoring programs and provide insight on specific sources, pathways and mechanisms by which pollution is occurring in these watersheds.

Although the geographic extent and applicability of these studies may be limited there is no substitute for the detailed information that they provide. To maximize the effectiveness of these special studies it is recommended that they be considered in terms of a coordinated effort to address a wide range of problems (including point sources) over time and be linked to the routine monitoring program.

It is recommended that the Region continue to support demonstration projects wherever possible.

Demonstration of successful management techniques to control pollution are a valuable way of gaining farmer acceptance. Participation by Ministry staff in such programs promotes an awareness of water quality issues by farmers.

It is recommended that the Region participate in experiments to evaluate the effectiveness of specific remedial practices in improving water quality.

Although information is available at the field level as to the effectiveness of various conservation tillage practices in reducing erosion (for example) there is a lack of information on the effect that such practices have on water quality. Furthermore, the extrapolation of field studies to the regional watershed scale deserves more attention.

5.2.3 MONITORING PROGRAMS

It is recommended that the routine monitoring program be adjusted to specifically address the effectiveness of programs established to reduce nonpoint source pollution.

Programs to control nonpoint source pollution are expensive. It is imperative that funds be spent effectively and that the results achieved (or lack of results achieved) be monitored and documented. A paper by O'Neill and Yaksich (28), states that reduction in phosphorus concentrations will be difficult to measure by monitoring programs alone. Efforts to measure program effectiveness should therefore incorporate both monitoring and modelling components.

It is recommended that more stations be established in the PWQMN to specifically monitor long term water quality trends with respect to agriculture.

Stations in the PWQMN are generally located on large watersheds and measure the combined effects of agriculture, urban and point sources. It is difficult (if not impossible) to separate out the general or specific effects of agriculture at such stations. It is recommended that stations be established on a number of small watersheds where agricultural land use predominates and can be monitored annually. These watersheds would be similar to those studied in the PLUARG program.

5.2.4 FURTHER STUDIES

It is recommended that the investigation of spatial and temporal patterns between land use and water quality undertaken in this project be expanded.

This study was limited to four water quality parameters and essentially five land use parameters. There is value in extending the analysis to additional water quality variables and land use patterns.

Of particular interest would be the inclusion of an additional parameter such as fertilizer usage which may affect water quality. In view of the findings with respect to total nitrogen it would be appropriate to extend the analysis to Nitrate-N, Nitrite-N and Ammonia.

The results of the tile drainage analysis were promising. These first cut estimates should be refined and compiled on a township basis. Total Nitrogen and tile drainage analysis should then be repeated at a finer level of detail (i.e. township) in an effort to better locate potential nitrogen problems.

Increasing total phosphorus trends may be occurring in some counties. This analysis should be updated using a more recent data base, possibly 1976 to 1985 in an effort to see if upward trends exist.

Respectfully,

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